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ON THE ANGULAR PITCH OF SQUARE-THREADED SCREWS.

By WILFRED LEWIS.

The efficiency of any mechanism is measured by the ratio of its useful work to the work consumed. This is always an important factor in determining the excellence of machinery, and it deserves special consideration in the case of feed and lifting screws, which often form essential elements of a design.

The screw may be used, in practice, either as a means of performing work, or for the purpose of binding and holding together various parts of machines or structures. In the latter case the thread is generally V-shaped, and its pitch and depth are determined by a recognized standard. Here the stability of constructions demands a small angular pitch, to prevent the possibility of jarring loose.

In the former case the square thread is the common and approved form, but no special standard of pitch is strictly adhered to, and inclinations ranging from 5° to 30° are often used.

The efficiency of a screw is increased by the reduction of its frictional work, which will be found to depend upon the coefficient of friction, the angular pitch of the thread, the shape of the thread, and

the diameter of the supporting step or collar. It is, therefore, desirable in cases where the screw is used to perform work, that its frictional resistance should be reduced to a minimum, and it is the object of this paper to investigate the relation between angular pitch and frictional work, and to derive a general formula by which the angle corresponding to the least amount of frictional work can be determined.

The first step necessary toward the reduction of friction is that the thread shall be square. This seems to be well understood, and calls for no special demonstration. It will suffice to say that the friction is proportional to the cosec. of the angle which the generating line of the thread makes with the axis of the screw.

The most common pitch for square threads is double that of V threads for the same diameter, but in the case of feed and lifting screws this is sometimes doubled, or even trebled, and it is found to be true that the work done in overcoming a given resistance or in lifting a given weight is thereby lessened.

The reason of this is apparent, for in screws of very fine pitch it will be seen that an undue amount of work is performed by the excessive sliding. On the other hand, it is also evident that if too coarse a pitch be used the power of the screw will be again lost in friction.

It therefore becomes necessary to determine that point at which the least amount of work will be absorbed by friction.

The angle at which this takes place must be a function of the frictional resistances, for were friction left out of consideration the work done in raising a given weight a given distance would be constant and independent of the pitch used.

The force necessary to slide a weight up or down an inclined plane is clearly demonstrated in Weisbach's Mechanics, and a similar construction will serve to determine the force required to overcome the resistance of a screw.

Let the right angled triangle ABC be the development of a spiral, the angle α being equal to the angular pitch, which is the angle of the spiral to a plane normal to the axis of the screw. Given the weight of the block O, represented by OW, to find the magnitude of the force parallel to AC, which will cause the block to slide up the incline AB. S_0 is the component of W along AB, and N_0 the normal component.

S_1 is the component of P along AB, and N_1 the normal.

$N_0 + N_1 = W \cos. \alpha + P \sin. \alpha$, $S_1 - S_0 = P \cos. \alpha - W \sin. \alpha$

Let φ = coefficient of friction, then

$$P \cos. \alpha - W \sin. \alpha = \varphi\ W \cos. \alpha + \varphi\ P \sin. \alpha$$

or $$P \cos. \alpha = W \sin. \alpha + \varphi\ (W \cos. \alpha + P \sin. \alpha)$$

multiplying by cosec. α

$$P \cot. \alpha = W + \varphi\ W \cot. \alpha + \varphi\ P$$

whence $$P (\cot. \alpha - \varphi) = W + \varphi\ W \cot. \alpha \text{ and}$$

$$P = \frac{W + \varphi\ W \cot. \alpha}{\cot. \alpha - \varphi} \qquad (1)$$

This force P multiplied by the mean radius of the screw will give the twisting moment required to raise a given weight without step or collar.

Similarly it may be shown that the force required to lower a given weight may be expressed by the equation

$$P_1 = \frac{\varphi\ W \cot. \alpha - W}{\cot. \alpha + \varphi} \qquad (2)$$

The moment required to overcome the resistance of a step or collar is equal to $\varphi\ W$ into the mean distance of the rubbing surface from the centre of the screw.

Let R = outside radius of collar.

Let r = inside " "

Then it can readily be shown that the mean radius

$$r_0 = \tfrac{2}{3} \frac{R^3 - r^3}{R^2 - r^2} \qquad (3)$$

The same formula may be used to determine the mean radius of the screw, but, inasmuch as r is seldom less than $\cdot 8\ R$, it will in most cases be sufficiently accurate to assume for the pitch diameter of the screw the diameter at the middle of the thread.

If d = pitch diameter of screw, and

D = " " " step or collar,

then $\frac{D}{d} = n$ will express the ratio of the effective lever arms of collar and thread.

The total force acting at the pitch line of the screw required to overcome all resistances will then be expressed by

$$P = \frac{W + \varphi\ W \cot. \alpha}{\cot. \alpha - \varphi} + n \varphi\ W. \qquad (4)$$

The work done in raising a weight through the distance BC, considered as unity, will be expressed by the equation, $P \cot. a =$ work done $=$

$$W. \frac{\cot. a + \varphi \cot.^2 a}{\cot. a - \varphi} + n \varphi W \cot. a. \qquad (5)$$

By differentiating and equating to zero, the following expression is obtained for the angle corresponding to the least amount of frictional work,

$$\cot. a = \varphi + \sqrt{\frac{1+\varphi^2}{1+n}}. \qquad (6)$$

Thus when the coefficient of friction and the value of n are known, the angular pitch corresponding to the greatest efficiency is readily obtained.

For example, let the coefficient of friction be ·15, and let the screw be supported upon a step equal in diameter to the root of the thread, in which case n will equal about ·5.

Then, applying the formula

$$\cot. a = ·15 + \sqrt{\frac{1+·0225}{1+·5}} = ·9525$$

$$a = 46° 23'$$

The most efficient pitch will in general be steeper than can be conveniently made in practice, and it is besides open to the objections of necessitating a large increase in diameter, and of diminishing the power.

In order to choose an advantageous pitch, with least sacrifice of power or material, plates 1 and 2 have been constructed.

In plate 1 abscissæ denote the angular pitch of the thread, and in plate 2 they denote the long or axial pitch in terms of the pitch diameter of the screw.

Plate 2 has been constructed by substituting the corresponding ordinates in plate 1, and is given as a form more convenient for practical use.

In these plates the coefficient of friction has been assumed at ·15, as determined from experiments to be described.

Ordinates from the horizontal line aa, measured to the curves de and df, are proportional to the force required at pitch of screw to raise or lower a given weight when $n = 0$.

Ordinates are to be measured from n, n', n'', when $n = ·5$, 1·5 and

3, respectively. From which it follows that the points of intersection of df with a, n, n' and n'' give the greatest angle at which the screw will stand without running down in those particular cases.

Ordinates measured from aa to gh and gk represent, respectively, the diameters of screws for equal torsional strength and for equal angular deflection.

Ordinates from BB to the curves A, N, N' and N'' represent the total work done when $n = 0$, ·5, 1·5 and 3.

BC = useful work done, and ordinates above CC = frictional work.

From plate 1 it becomes evident that by the reduction of n' to n, or a change from an ordinary collar to step bearing, that a screw whose pitch was 5° might be increased to 13° without sacrifice of power, and with a saving of ·6 of the work consumed by friction.

To find the force required to turn a V-threaded screw, let β = angle which generating line of thread makes with the axis, then from equation (4)

$$P = \text{cosec. } \beta \frac{W + \varphi W \cot. a}{\cot. a - \varphi} + n \varphi W. \qquad (7)$$

In the U. S. standard V thread, $\beta = 60°$ and $a = 2\frac{1}{2}°$ about, and the value of n for a nut or bolt head = 1·5 nearly.

Then, by substitution in the above formula,

$$P = \left(1{\cdot}15 \frac{1 + {\cdot}15 \times 22{\cdot}9}{22{\cdot}9 - {\cdot}15} + 1{\cdot}5 \times {\cdot}15\right) W = {\cdot}45 \ W$$

When friction is disregarded P should equal tan. a $W = {\cdot}0437$ W. Hence it is evident that the stress upon a standard V threaded bolt will be only $\frac{{\cdot}0437}{{\cdot}45}$, or ·1 of the stress calculated in disregard of friction, and this has been actually confirmed by experiment.

Similarly it may be shown that the stress upon a common square threaded bolt whose angular pitch = 5° is ·19 of that calculated in disregard of friction.

The stress exerted by a given force P will be practically the same in either case, although the square thread is double the pitch of the V, and this is a striking proof of the disadvantage of using very fine pitches.

The coefficient of friction ·15 was determined by experiments upon the feed screw of a 36-inch vertical drill at the machine works of Wm. Sellers & Co. The essential features of the apparatus are shown in Fig. 2.

The feed screw to which the spindle is attached is suspended in a cast iron nut, and is prevented from revolving with the nut by links at A.

A cord was wound around the circumference of this nut, to which, after passing over a pulley, weights were suspended at F. Weights ranging from 50 to 2000 lbs. were suspended at W, and the force at F necessary to start the nut as well as to keep it in motion was carefully determined in each case.

It was in general found that the force required to start the nut was about 1·3 times that required to keep it in motion, and that the force required to keep it in motion varied slightly with the speed, growing less as the speed increased.

But inasmuch as there was no available means of determining the rate of motion, the speed was kept as slow as possible. Due allowance was made for the friction of the pulley and the coefficient φ calculated by substitution in equation (4).

It is sometimes necessary, apart from the questions of torsional strength and angular deflection, to know the combined effects of torsion and tension upon a movable nut worked by the screw, in order to insure steadiness of motion. In other words, to find the ratio of the diameters of screws of various pitches in which the total resilience shall be constant.

Thus, let it be required to find the diameter of any screw whose total resilience shall be equal to that of a screw whose diameter is unity and angular pitch indefinitely small.

The elastic extension of wrought iron under a proof load of 30,000 pounds, is, according to D. K. Clark, about ·0011 times its length, and it can be deduced, from the formulæ for deflection given by the same author, that a load of 30,000 pounds applied at the circumference of a shaft of 1 inch section will produce a circular deflection of ·0154 times the length of the shaft. It therefore follows that when $P = W$ the ratio of circular deflection to linear extension will be $\frac{\cdot 0154}{\cdot 0011} = 14$, and if the linear extension be assumed at unity the circular deflection will be 14 times $\frac{P}{W}$, as calculated by equation (1), or by 14 P when W is assumed at unity, and for the sake of simplicity this assumption will be made in all subsequent formulæ.

The resilience of extension is felt directly by the movable nut, but that of circular deflection must be multiplied by the tangent of the angular pitch, to determine its effect upon the steadiness of motion. Both vary inversely as the square of the diameter of the screw when the resistance is constant, and hence the conditions necessary to insure equal steadiness of motion in screws of various pitches, having the same resistance to overcome, are expressed by the equation

$$\frac{1 + 14\ P \tan.\ a}{d^4} = \text{a constant.}$$

The ratio of the diameters can, therefore, be determined by the equation

$$d = \sqrt[4]{1 + 14\ P \tan.\ a} \qquad (8)$$

By substituting the values of tan. a the following values of d are obtained:

When $a =$	$0°$ $d = 1$	When $a =$	$5°$ $d = 1{\cdot}13$
" $a =$	$10°$ $d = 1{\cdot}35$	" $a =$	$20°$ $d = 1{\cdot}94$
" $a =$	$30°$ $d = 2{\cdot}74$	" $a =$	$40°$ $d = 3{\cdot}64$
" $a =$	$50°$ $d = 5{\cdot}14$	" $a =$	$60°$ $d = 7{\cdot}75$

For steel the ratio of circular deflection to linear extension may be taken at 7, and a curve similar to that for wrought iron calculated by the formula

$$d = \sqrt[4]{1 + 7\ P \tan.\ a} \qquad (9)$$

The curve of diameters for uniform total resilience in wrought iron is represented by dl, and thus the power, strength, stiffness, resilience and frictional work for any pitch can at once be seen.

Another curve, showing the comparative steadiness of motion in screws of the same diameter but of different pitches, might be computed by the formula $1 + 14\ P$ tan. $a =$ comparative resilience of screws of constant diameter.

The application of the preceding principles to differential screws shows an enormous loss in frictional work without the commonly supposed gain in power.* If, in Fig. 2, the cast iron nut which revolves upon its bearing should be made to move longitudinally, by having a thread, whose pitch should be in the same direction as the internal

* The word power is used advisedly in the sense of force, and nothing more than the relation $\frac{W}{P}$ should be understood by it.

thread, cut upon its outer surface, then the advance of the spindle would be measured by the difference in axial pitch of the two screws.

The throw of the spindle, however, would be necessarily much restricted by such an arrangement, and the substitute is sometimes resorted to, of making the screw and nut both revolve in the same direction by suitable gearing.

In either case the object of the device is to multiply the power without reducing the size of the thread to that of a corresponding simple screw and nut.

How much the power may be multiplied can be determined from a general solution for each case.

In the first case, let

a = diam. of external screw; e = axial pitch of external screw;
b = " internal " f = " " internal "
$\frac{b}{a} = d$ = ratio of diameters; $\frac{f}{e} = p$ = ratio of pitches;
α = angular pitch of external screw;
β = " " internal "

Then cot. $\alpha = \frac{\pi a}{e}$, and cot. $\beta = \frac{\pi b}{f} =$ cot. $\alpha \frac{eb}{af} = \frac{\pi d a}{pe}$

The force required at pitch line of external screw to move it against a resisting weight can be determined from equations (1) and (2), and may be expressed by

$$F = P + P^1 = \frac{1 + \frac{\varphi \pi a}{e}}{\frac{\pi a}{e} - \varphi} + d \frac{\frac{\varphi \pi d a}{pe} - 1}{\frac{\pi d a}{pe} + \varphi} \qquad (10)$$

and the force required to turn it in the opposite direction will be given by the equation

$$F_1 = P_1 + P = \frac{\frac{\varphi \pi a}{e} - 1}{\frac{\pi a}{e} + \varphi} + d \frac{\frac{\varphi \pi d a}{pe} + 1}{\frac{\pi d a}{pe} - \varphi} \qquad (11)$$

The direction in which the external screw should be turned in order to perform work against resistance, depends upon the relative magnitudes of e and f.

When $e > f$, equation (10) expresses the force required to raise a

weight, and equation (11) the force required to lower it, and *vice versa*.

For example, let $a = 2 \cdot b = 1 \cdot e = \cdot5$, and $f = \cdot4$, then $d = \cdot5$ and $p = \cdot8$, and applying formula (10):

$P = \cdot2325$, $P_1 = \cdot0111$, and consequently $F = \cdot2436$

Also from formula (11):

$P_1 = \cdot07$, $P = \cdot1115$, and $F_1 = \cdot1815$

Here there is actually less power gained than could have been derived from the outside screw alone when used without step or collar.

The total work done is given by the formula

$$U = \frac{F \pi a}{e - f} = \frac{\cdot24 \times 3\cdot14 \times 2}{\cdot1} = 15\cdot7$$

times the useful work.

When the screw and nut both revolve with different angular velocities there are three pairs of rubbing surfaces, the step upon the screw, the collar upon the nut, and the screw threads themselves.

Let n = ratio of effective diameters of step and screw;
" n^1 = " " " " nut "
" a = angular pitch of screw;
" v = " vel. "
" v^1 = " " nut.

Then, when $v > v^1$ the force required to turn the screw at its pitch line against a resistance can be expressed by the equation

$$F = \frac{1 + \varphi \cot. a}{\cot. a - \varphi} + n\varphi + \frac{v^1}{v}\left(n^1\varphi - \frac{1 + \varphi \cot. a}{\cot. a - \varphi}\right) \qquad (12)$$

and when $v^1 > v$, the equation becomes

$$F = \frac{1 + \varphi \cot. a}{\cot. a - \varphi} + n^1\varphi + \frac{v}{v^1}\left(n\varphi - \frac{1 + \varphi \cot. a}{\cot. a - \varphi}\right) \qquad (13)$$

The force required to lower a weight when $v > v^1$ is

$$F_1 = \frac{\varphi \cot. a - 1}{\cot. a + \varphi} + n\varphi + \frac{v^1}{v}\left(n^1\varphi - \frac{\varphi \cot. a - 1}{\cot. a + \varphi}\right) \qquad (14)$$

and when $v^1 > v$ the equation becomes

$$F_1 = \frac{\varphi \cot. a - 1}{\cot. a + \varphi} + n^1\varphi + \frac{v}{v^1}\left(n\varphi - \frac{\varphi \cot. a - 1}{\cot. a + \varphi}\right) \qquad (15)$$

To take an example, let $n = \cdot5$, $n_1 = 1\cdot5$, $a = 5°$, $v = 3$, and

$v^1 = 2$, then from equation (12) $F = \cdot 305$ The ratio of the total work consumed to the useful work done can be obtained from this by the formula

$$U = F \cot. a \frac{v}{v - v^1} \qquad (16)$$

when $v > v^1$, or by

$$U = F \cot. a \frac{v}{v^1 - v} \qquad (17)$$

when $v^1 > v$, and for the present case $U = 10 \cdot 46$. The same screw working in a fixed nut would give $P = \cdot 315$ and $U = 3 \cdot 6$, and thus from the above formula the power and efficiency for either form of differential screw can be determined, and the inefficiency and absurdity of any particular case thereby demonstrated.

Explosion of Carbonic Acid in a Coal Mine.—Delesse gives an interesting account of a remarkable explosion in the coal mine of Rochebelle. Two miners who were at work in a shaft, at a depth of 345 metres (377·3 yards), heard a noise like a blast, but shorter; less than a minute afterwards they heard a second report, louder than the first, but which was not heard by the attendant at the opening of the shaft. Their lamps were extinguished and they felt great oppression, but were able to give the signal so as to be drawn to the surface, and thus escape death. Three miners were suffocated in the galleries leading from the shaft. The explosions were at first attributed to fire-damp, but the bodies and clothing of the victims showed no trace of fire; none of the loose gunpowder or cartridges took fire. No fire-damp has ever been observed in the mine, but occasional outbursts of carbonic acid have been noticed and guarded against by special ventilation. On examining the locality of the explosion a hole was found not less than 6 metres deep (6·562 yards), and of capacity sufficient to have contained about 76 tons of coal. Delesse attributes the explosion to the action of sulphuric acid, generated by iron pyrites, gradually dissolving in the subterranean waters and penetrating to underlying beds of limestone. The gas penetrating the crevices of the coal would accumulate, producing a constantly increasing pressure until it acquired force enough to make the explosions.—*Comptes Rendus.* C.

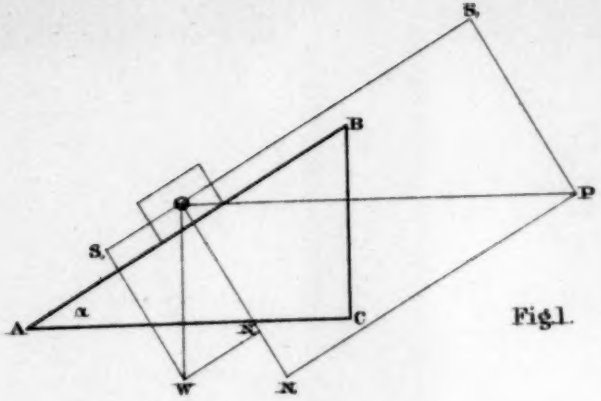
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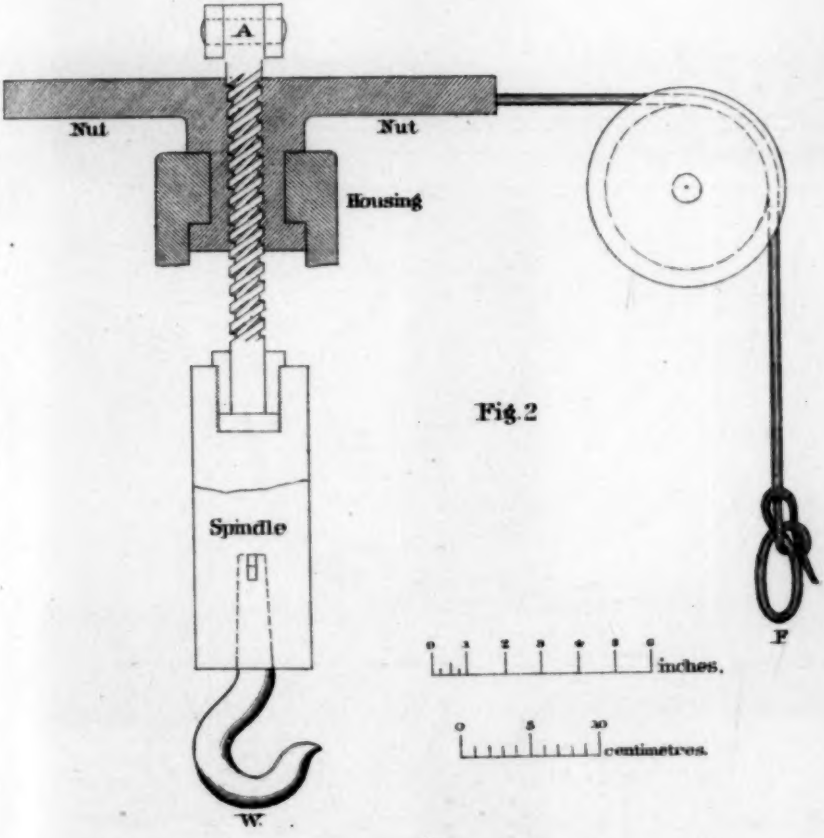
Fig.1.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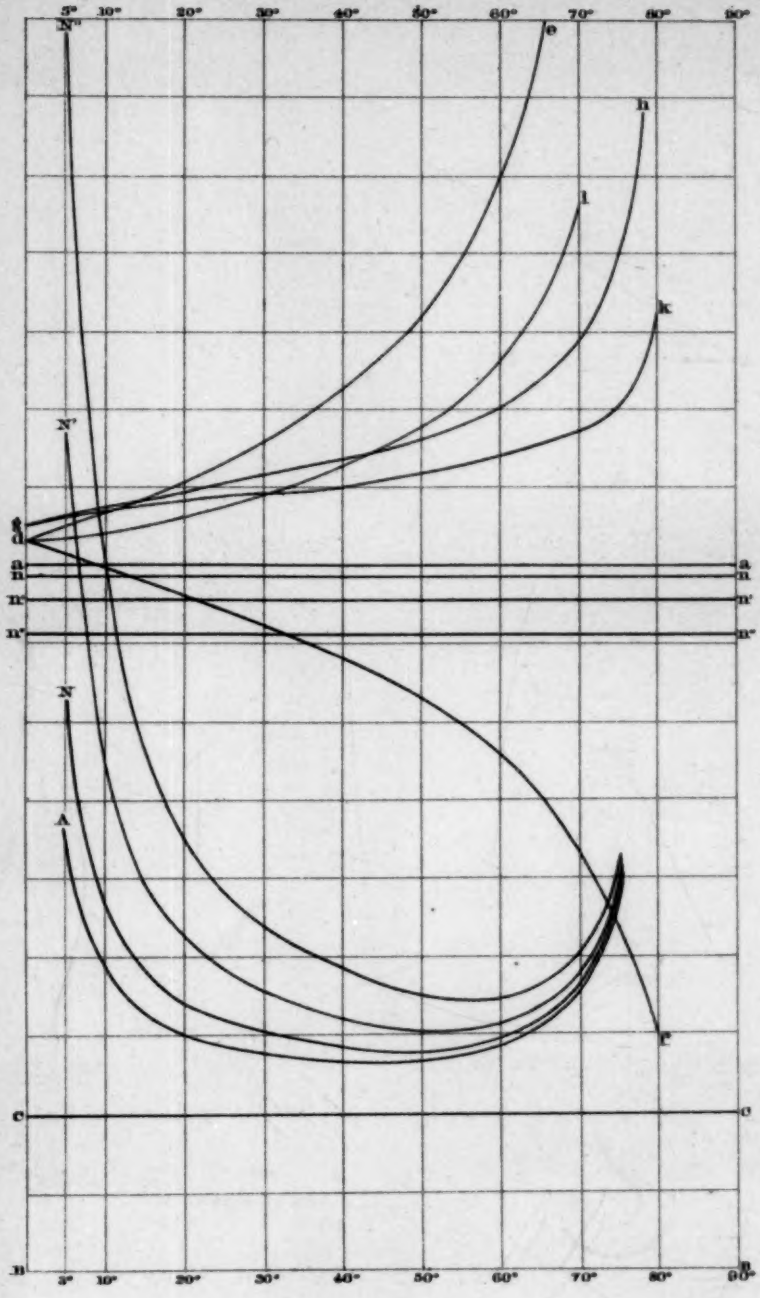
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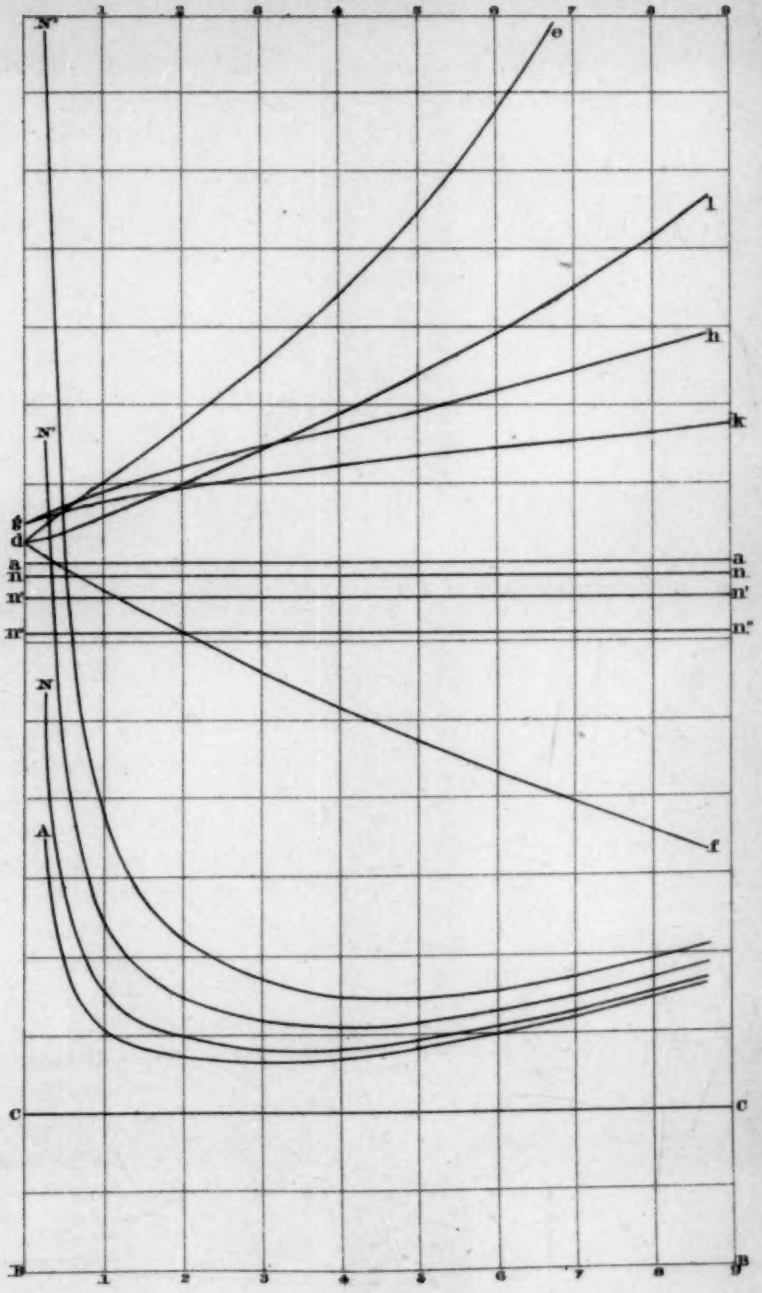
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DEPHOSPHORIZATION OF IRON.

By F. GAUTIER.

A paper read before the Society of Civil Engineers of Paris, July 4th, 1879.
Translated by CHAS. E. BILLIN.

Dephosphorization is a problem of great importance in metallurgy. In the proportion of *one per cent.* phosphorus renders iron easily fusible, a property precious in the foundry, without doubt, but unfortunately accompanied by a very great fragility. *One-half per cent.* renders the iron more malleable and easier to weld when hot, but the fibre is replaced by a flat grain without resistance.

In steel low in carbon, 0·1 *per cent.* renders rolling impossible, prevents tempering, and gives a brittle metal unfit for any use.

I will not enlarge upon these disadvantages of phosphorus; they are known to you all. It will be sufficient for me to recall them in passing.

Unfortunately, phosphorus is of very common occurrence in the ores of iron. The most abundant ores are the poorest in iron, and also contain the greatest per cent. of phosphorus. These ores are characterized generally by *one-half per cent. of phosphorus, accompanied by about thirty per cent. of iron.* Iron made from them contains 1·5 to 2·0 per cent. of phosphorus.

In the ore the phosphorus is generally in the state of phosphate of lime or alumina. These phosphates are not decomposable by heat, and are irreducible by carbon or carbonic oxide. In order to displace the phosphoric acid, the presence of silica is necessary. This forms an earthy silicate, and then permits the carbon, or carbonic oxide, to exercise its reducing action and to free the phosphorus.

In the blast furnace and in presence of an excess of iron, these reactions lead finally to the production of phosphuret of iron, which disseminates itself through the metal. When the phosphorus is in the state of metallic phosphate, its reduction takes place without the intervention of silica, and at a lower temperature.

It is thus that *all the phosphorus of the furnace burden, ore, flux and fuel concentrates itself in the pig metal,* and this is even more the case

when the furnace is working very cold, for then traces of this dangerous metalloid are found in the slag.

It is easy to comprehend, in the presence of this fatal accumulation of phosphorus in the pig metal, which is the first material in the iron and steel industry, that attempts have been made to purify the ores.

I spoke to you, some years ago, of attempts at dephosphorization which I had witnessed in Bohemian works. At Kladno they sought to dissolve the phosphate of lime and of alumina of the ore by scouring with a solution of sulphurous acid. They only succeeded in a reduction of 30 per cent., and this at an expense of 30 francs ($6) per ton of metal. It was a cumbrous process, not practical, and has been almost forgotten.

What is to be done, then? Attack the pig metal direct.

To be better able to judge of the real progress, it will be well to review the different methods employed.

Dephosphorization in Puddling.—In the reverberatory furnace, on a cast iron bed-plate covered with oxide of iron, the metal is kept in a liquid state. The oxidizing action produced by the contact with the oxide of iron, by the free oxygen from the gases of the hearth, and by the air, which enters at the doors, is further facilitated by the energetic working of the metal, which renews the exposed surfaces. This constitutes the work of puddling.

The most oxidizable bodies, silicium and manganese, are the first to pass off in the slag. As to the phosphorus, the final elimination of which generally attains to 60 per cent., it is usually admitted that it is transformed in part into phosphate of iron, but above everything else its elimination is attributed to the *liquation*. When the metal clears itself of foreign elements that it contains it becomes less fusible, and passes into a solid state in the midst of liquid slag, which surrounds it. It is at this moment that occurs the greatest purification during the puddling.

The *liquation* certainly plays a very important *role*, but the single process of the fusion of the iron in contact with the oxide of iron of the bed of the furnace, constitutes a dephosphorization of 40 per cent. This is a point to which I wish to call your attention for a moment, because it throws a certain light on the processes which we will study together later.

We find in the scientific studies of M. Snelus, on Dank's Mechanical Puddling, the following results:

Brand		Pig metal	Melted Iron.	Puddled Iron.
Staffordshire (grey),	Carbon	2·74	2·55	trace
	Silicon	2·25	0·92	"
	Phosphorus	0·63	0·35	0·24
Cleveland (grey),	Carbon	3·18	2·83	trace
	Silicon	1·20	0·80	"
	Phosphorus	1·49	0·91	0·46
(white),	Carbon	2·30	1·30	trace
	Silicon	0·89	0·18	"
	Phosphorus	2·17	0·86	0·38

This is a fact which I have equally verified in melting some of the phosphoric iron of the Moselle on the bed of a furnace and then puddling it.

Pig metal,	. . .	1·65 per cent. of phosphorus.	
Melted iron,	. . .	0·90 "	"
Puddled iron,	. .	0·64 "	"

The total dephosphorization is 61 per cent., of which 46 per cent. is due to the action of fusing it on the bed of the furnace with oxide of iron. Only 15 per cent., therefore, is due to further oxidation and to liquation.

Special Dephosphorization in Puddling with Manganiferous Iron.—When puddling has for its object the production of a specially pure iron, it is accomplished by adding manganese. This is a very recent industry, which had its origin in Belgium, whence it afterwards extended into Germany and a part of France.

To the iron containing phosphorus is added spiegeleisen in such quantities as to have in the mixture from 2 to 3 per cent. of manganese; then it is puddled at a high temperature. The presence of manganese retards the purification and increases the amount of necessary working. The number of charges, in a turn of twelve hours, with a furnace for two workers, falls from 8 or 9 to 4, and the product decreases from 1500 kilogrammes to 900. The waste or loss is not very great because it is hidden by a considerable consumption of scrap iron, which is used to maintain or keep up the furnace bed, but the dephosphorization is energetic and can attain to 97 per cent. With an iron containing 1·6 per cent. of phosphorus, which, without manganese would yield after puddling 0·6 to 0·7 per cent., there is often obtained an iron which contains only a half-thousandth of phosphorus, as shown in the following table:

	Pig Iron.	Melted Iron.	Puddled Iron.
Carbon,	3·5	3·3	0·15
Silicon,	1·1	0·3	trace
Manganese,	2·6	0·6	0·06
Phosphorus,	1·6	0·5	0·05

The simple fusion of the iron has led to a dephosphorization even greater than shown in preceding examples.

En résumé, this is a very satisfactory purification, but it is excessively expensive and can only lead to the satisfaction of very special needs.

The Heaton Process created some stir in England ten years ago, and has been the object of very complete and interesting studies on the part of M. Gruner.

Into a cylindrical vessel of sheet iron, lined with refractory earth, is poured the molten metal. The bottom of this vessel is a plate of cast iron, or, better still, a piece of sheet iron, 4 millimetres thick, which is pierced by holes and destined to be melted down by contact with the molten iron, which then tumbles into a sort of caldron containing nitrate of soda. This salt is decomposed instantly, and produces compounds of oxygen and nitrogen, which traverse the column of liquid metal, and make it undergo in a few moments of time an energetic purification. An iron with 1·5 per cent. of phosphorus gave a half solid product, still having 0·6 to 0·9 of phosphorus and 0·14 to 0·16 of silica. This was not cast iron, for the decarburation was considerable, and neither was it wrought iron nor steel. The waste was only 5 or 6 per cent., but the amount of nitrate used ought to be more than 10 per cent., in order to obtain good results. In short, the process was incomplete, expensive, and could only furnish the first material for the manufacture of steel in the Martin-Siemens furnace; therefore it was not used.

Here stops the account of means for dephosphorization placed at the disposal of metallurgists, until within the last few years.

The Bessemer Process gives no purification whatever, but on the contrary, a concentration of the phosphorus in proportion to the waste.

It is thus that with Cleveland iron, containing 1·46 per cent. of phosphorus, Mr. I. Lowthian Bell obtained steel with 1·62 per cent., and at the Essen Steel Works, with the same iron, was produced a steel containing 1·77 per cent.

In the *Martin-Siemens* process, which produces steel on the bed-

plate of a reverberatory furnace by melting a mixture of cast iron and scrap, either wrought iron or steel, there is the same concentration of phosphorus.

Whence comes, then, this anomaly? The theory of dephosphorization is not yet complete, but we agree more or less in acknowledging that several conditions concur to produce purification.

1st. *Oxidizing action*, for transforming the phosphorus into phosphoric acid.

2d. *Basic slag*, in order to permit the absorption of silica, which is of necessity encountered in all metallurgical operations, and to facilitate the combination of the phosphoric acid produced.

3d. *Liquation*,* or the separation of the solid product from the phosphoric slags which proceed from the refining and flow off in a liquid state.

Finally, *the temperature*, to which of late has been attributed a certain influence, either that its elevation decomposes the phosphates produced, or, rather, that the basic affinities of the silica are quickly excited and set the phosphates at liberty.

All these conditions certainly have not equal influences, but each seems to have its own.

In puddling we meet an energetic oxidizing action, produced as much by the action of the peroxide of iron which constitutes the furnace lining as by the peroxidized slag under the influence of free oxygen contained in the products of combustion. The air entering at the doors is another cause of oxidation which we must not forget. The *basic state* of the slag is not doubted, since the bed of the furnace is entirely covered with oxide of iron, and as the slag *en présence* contains commonly 10 to 12 per cent. of silica, and rarely more than 20 per cent. As to the *liquation*, it is characteristic of this operation; there has been, perhaps, an exaggerated importance attached to this portion of the process in explaining the elimination of phosphorus; some one has even gone so far as to say that wrought iron forming (or "coming to nature") in the midst of a phosphoric slag is like ice, free from salt, being formed by the freezing of sea water. *The temperature* in puddling is relatively low; moreover, it has been found in the treatment of certain iron, very high in phosphorus, that it was important, in order to obtain a good purification, not to have the heat too intense.

* This portion of the puddliug process is called by American puddlers "coming to nature." C. E. B.

We see, then, that in puddling, all the conditions more or less known as necessary to dephosphorization are to a great measure fulfilled, and make of this process an energetic method of purification.

In the Heaton process what do we find? The *oxidizing action*, although of short duration (it lasts only from 2 to 5 minutes), has here an intensity peculiar to this process; it is an explosive, instantaneous action, utilizing the oxygen as soon as it is free, or feebly combined with nitrogen in easily dissociable products. The *slag is basic*, for it contains a minimum of 30 per cent. of soda, which has powerful affinities, and 10 to 20 per cent. of oxide of iron; it also contains sometimes 54 per cent. of silica. The product was pasty and only half fluid; there was a kind of *liquation*, which did not show itself in any way except when the spongy metal, filled with slag, was reheated and hammered. Finally, the *temperature* is relatively low, and certainly would not permit the phosphate products being decomposed either by the heat alone or by the exaltation of the basic affinities of the silica. This is certainly a group of favorable conditions, which explain sufficiently the purifying character of this process.

It will not be the same if we consider the Bessemer operation. Although the oxidizing action is of an extraordinary intensity, the slags are very silicious, containing from 40 to 50 per cent. of silica, which is derived as much from the silica of the metal as from the lining, essentially silicious, of the converter. It is not necessary to speak of the liquation, since the product is extremely fluid, like the slag which covers it. As to the temperature, it is excessively high, and we can reasonably believe, as regards this portion of the process, that it is sufficient to prevent all stable combinations of the phosphoric acid with the slag.

These conditions, that we also find in the Martin-Siemens, with, however, a more feeble oxidizing action, certainly do not constitute a satisfactory *ensemble* when dephosphorization *alone is considered*, and we can scarcely be astonished that the purification amounts to nothing in either one or the other of these processes for the manufacture of steel.

One can even go further, and say that most prominent metallurgists had lost hope of applying to steel any method of dephosphorization.

In presence of these difficulties, that neither the chemist nor the empiricist seemed able to surmount, we had taken up with interest a solution which permitted leaving in the steel a proportion of phospho-

rus five or six times greater than what had been thought possible before this.

M. Euverte explained, some years ago, how, thanks to the employment of ferro-manganese, a reducing agent more concentrated and energetic than spiegel, the final oxidation of the metallic bath in the Bessemer and Martin-Siemens processes, could be raised without introducing into the steel so large a quantity of carbon. He showed, also, how the diminution of carbon permitted leaving in the steel three or four thousandths of phosphorus without injuring the product sufficiently to prevent its being used for rails. This was a vast field opened to the employment of iron rails, for their conversion in the Martin-Siemens furnace into steel rails of a good quality, containing phosphorus; but it was not the dephosphorization of impure pig metal.

The above has been the necessary preface to the important question which is the subject of this communication.

From this point the subject divides into two portions:

1st. Dephosphorizing operations, without the elimination of the carbon, or furnace purification (*mazéages epurateurs*).

2d. Manufacture of steel from phosphoric pig metal.

1st. Furnace Purification.

Mr. I. Lowthian Bell, whose numerous and interesting works on the blast furnace have given him a reputation of the first order, has obtained remarkable results in the dephosphorization of Clarence pig iron, of which the extreme limits of composition are as follows:

Carbon, ...	3·670 to 3·20
Silicon, ...	2·810 to 1·50
Sulphur, ...	0·102 to 0·02
Phosphorus, ...	1·930 to 1·08

This is iron made from Cleveland ores without mixing those of other origin.

We have seen that, in treating Cleveland iron containing 1·46 per cent. of phosphorus, by the Bessemer process, Mr. Bell obtained steel which contained 1·62 per cent., the lining of the converter being *gannister*, or nearly pure silica.

With the same lining and an addition of 30 per cent. of pure oxide of iron mixed with the melted slag, he did not obtain any better result. He had then an intense boiling, but no dephosphorization. Trying to

account for his unsuccess, Mr. Bell attributed it to the imperfect contact of the metal with the oxide of iron, and made another attempt.

In the same converter he blew the metal beyond the ordinary stopping point in Bessemer operations, until 25 per cent. of the iron had been oxidized. He hoped that, owing to this, the oxyd of iron, in a nascent state, would act more energetically, and to obtain a more intimate contact with the metallic bath. The only result was an augmentation of 24·8 per cent. in the proportion of phosphorus, which was thus concentrated in the product in exact proportion to the loss.

Renouncing then the attempt to produce steel directly from phosphoric iron Mr. Bell turned to another side. The failure of the Bessemer process in these attempts seemed to him to be principally due to the elevation of the temperature, which led, without doubt to the decomposition of the phosphate of iron in proportion as it was produced.

At the Bowling furnace he treated a certain quantity of his iron and obtained the following results:

	Pig metal.	Refined pig.
Carbon,	3·12	2·50
Silicon,	2·80	0·12
Sulphur,	0·11	trace.
Phosphorus,	1·47	0·84

This was a dephosphorization of more than 40 per cent. In analyzing the phenomena, we find that this operation took place in a vessel with walls of cast iron, cooled by a current of water, and under the action of an oxidizing blast of low temperature. As the slag contained scarcely 25 to 30 per cent. of silica we could reasonably attribute to the oxide of iron, which it contained in large quantities, an important action in the dephosphorization.

In cooling slowly, some metal taken from one of the Clarence furnaces, in contact with melted oxide of iron, Mr. Bell obtained results analogous to those which were given for the experiment at the Bowling furnace.

	Pig metal.	Metal having passed over the oxide of iron.	Refined metal.
Carbon,	3·305	2·731	2·500
Silicon,	2·163	0·028	0·120
Sulphur,	0·102	0·056	trace.
Phosphorus,	1·515	0·838	0·840

Employing then the Godfrey and Howson mechanical puddler, which is composed of a sort of converter able to turn on itself or to incline at any angle, and which is heated by a jet of gas entering by the mouth, Mr. Bell made numerous experiments in treating Clarence iron. The lining was oxide of iron, of which the composition varied, so that the oxide melted or simply heated as added. Below are the results obtained:

	Pig metal.	Metal after treatment.
Phosphorus, . .	1.50	0·23
Silicon, . . .	2·06	0·10

The purification was very satisfactory, as may be seen; but everything depends on the temperature, and the feeble capacity of the vessel would be found to be the cause of projections which would condemn the apparatus.

For his last experiments Mr. Bell designed an oscillating furnace having the form of a cylinder four metres long and one metre in diameter. A longitudinal partition separated it into two parts, and served to insure the stirring up of the liquid metal, and its contact with the melted oxide of iron at each movement of the apparatus. In ten minutes a charge of 700 kilogrammes of metal was submitted to sixty or eighty oscillations. The operation was stopped when bubbles of carbonic oxide were seen traversing the liquid mass and coming to the surface, burning in the form of blue flames. As in preceding experiments, the nature of the oxide of iron was varied, and Mr. Bell succeeded, even with calcined Cleveland ores, in producing a remarkable dephosphorization. The waste was from 0· to 2·5 per cent.

Below are given, from information obtained from Mr. Bell, some of the results:

	Metal before treatment.	Metal after treatment.
Carbon, . .	3·5	3·25 to 2·75
Silicon, . . .	1·7	0·5 to 0·20
Phosphorus, . .	1·5	0·1 to 0·05

This is, without any doubt, a very good dephosphorization without notable decarburation; the product is purified metal that can be cast, in order to employ it afterwards in the manufacture of open hearth steel. This is what was done at the Woolwich Arsenal, and the truly remarkable products, which secured for Mr. Bell a high reward at the Universal Exposition of 1878, were obtained in this manner.

Without pretending to have completely solved the question of the most suitable apparatus, Mr. Bell stopped temporarily his interesting researches.

MM. Narjes and Bender, engineers of the steel works at Essen, have put in practice a *purifying furnace*, for which the patent was taken out by the firm of F. Krupp.

The pig iron is melted in a cupola, though it might be taken with advantage from the blast furnace direct. On the inclined bed of a revolving furnace analogous to Pernot's furnace, and heated by Siemen's system, is a lining of oxide of iron. We have not the details as to the agglomeration of this oxide of iron, but it is easy to imagine that it might be attained by working at a higher temperature than that at which later work is carried on. Moreover, there is formed a purifying bath, in melting, more or less completely, on this bed a certain quantity of iron ore which naturally contains an average amount of silica. This bath has a thickness of about 30 centimetres. The iron to be refined is slipped into the furnace, which is then turned, at first slowly, with a speed of only two revolutions per minute, which is afterwards increased to five; the movement is given by a six-horse power machine which, however, is found to be a little light for this work.

According to M. Wedding, Professor in the School of Mines, at Berlin, the operation never takes more than ten minutes for a charge of 4 tons of metal. As in the last experiments of Mr. Bell, the operation is stopped when a disengagement of the carbonic oxide is perceived. The amount of waste is variable. Generally slight, it is sometimes even nothing, owing to the reduction of a part of the oxide employed, under the action of the silicon, and perhaps of the phosphorus. By this process 80 tons can be treated every 24 hours, with a consumption of 7 to 8 tons of coal and 15 tons of ore. It is said that 8 to 10 francs (80c. to $1.00) is the entire cost of the operation, but this is not at all sure. As to the dephosphorization, it is from 75 to 80 per cent., and would be facilitated by the presence of a small amount of manganese.

	Carbon.		Phosphorus.	
Metal.	Before.	After.	Before.	After.
A	3·17	3·02	1·220	0·303
B	3·90	3·75	0·630	1·131
C	3·81	3·56	0·450	1·108

This industry, in the works of Essen, served only for the demonstration of the process or to experiment with pig iron which people wished to have treated. The Forge Company, of Dillingen, started this method of manufacture, at Hussigny, near Longwy, France, and built a blast furnace in such a position that the metal could be let directly into the purifying apparatus.

There is a certain analogy between the purifying processes of Mr. Bell and of Messrs. Narjes and Bender. Their common character is a marked dephosphorization without hastening decarburation. We have said nothing of the removal of silicon at Essen; it is evidently complete, and prevents later treatment of the metal by the Bessemer process.

These refined metals can be usefully employed in puddling, for the improvement of the puddled iron; or, if the proportion of phosphorus is sufficiently small, they can be used in the Martin-Siemens furnace for the manufacture of *phosphoric steel* rails.

Why is the operation stopped at the moment when decarburation commences? It appears to us that there are two reasons: the result obtained would not be perceptibly improved by prolonging the operation; the result would, perhaps, be in part destroyed by the reducing action of the carbonic oxide, as we will explain further on; besides, it would sensibly increase the expense in removing carbon which would have to be replaced. Moreover, the apparatus does not permit, on account of either the manner in which it is built or its temperature, the necessary conditions for the production of steel; we would obtain wrought iron.

2d. Manufacture of Steel from Phosphoric Pig Metal.

Thomas and Gilchrist Process.—Two young men, Mr. Sidney Thomas, chemist, studying metallurgy only as an amateur, and Mr. Percy Gilchrist, chemist of the Blaenoven Works, Wales, and a recent graduate of the School of Mines, London, associated themselves to try and find some method of dephosphorization in using the Bessemer process.

Starting with the idea that a basic lining was indispensable, they constructed a small converter, capable of treating only a few kilogrammes of metal. They lined it with lime cemented together with a silicate of soda, and obtained results which attracted the attention of Mr. Edward Martin, director of Blaenoven. He authorized them to

construct a converter of the capacity of 200 kilogrammes, which they furnished with the same basic lining. To absorb the phosphoric acid produced and to preserve the lining from the destructive action of the silica formed by the oxidation of the silicon of the metal, they employed various basic additions, of which lime and oxide of iron were the elements. They attempted at the same time to push the operation beyond the point of decarburation, that is *to overblow*, and they thus obtained a remarkable dephosphorization.

These experiments were repeated at the Dowlais Works, with a full sized converter, capable of treating five to six tons of metal. The preceding results were confirmed, but some accidents occurring to the lining stopped their experiments; they were continued at the steel works of Bolckow Vaughan, at Eston, near Middlesborough (Cleveland).

Mr. Windsor-Richards, director of this establishment, with the co-operation of Messrs. Thomas and Gilchrist, imparted a strong impulse to these researches.

A lining of oxide of iron and additions of oxide of iron alone, without mixing any lime, did not succeed; the reactions were too rapid, and the operations rendered impossible by the spouting and boiling. They were therefore obliged to return to the earthy lining.

An attempt at the manufacture of bricks from dolomite showed all the difficulties of the problem. After pulverizing this material, working it up with water, moulding and baking it, there was a reduction of 33 per cent. in volume and a loss in weight of 45 per cent. Several accidents occurred: sometimes the unequal heating led to the twitching of the mass in baking and to numerous ruptures; sometimes, on account of insufficient heat, the bricks obtained decrepitated like lime upon exposure to the air; or, at other times, owing to an excess of heat, the bricks ran together and melted with the oven. They succeeded, however, in determining this first part of the problem. It seemed, moreover, that this question of lining had several satisfactory solutions.

Mr. Gilchrist recommends the following composition:

Silica, ...	10
Alumina and oxide of iron, . .	4 to 6
Magnesia, ...	30
Lime, ...	54 to 56

The bricks employed in the operations that we have studied at Eston had the following composition, which differs notably:

Silica,	9·50
Alumina,	10·00
Peroxide of iron,	4·46
Magnesia,	21·50
Lime,	50·25
Soda,	4·00

This is dolomite agglomerated with silicate of soda.

Finally, Mr. Riley makes his bricks as follows: He takes pulverized dolomite, which he mixes with petroleum or some analogous mineral oil, which gives the bricks the following composition:

Silica,	8·85
Alumina and oxide of iron,	4·00
Magnesia,	35·00
Lime,	51·00

A filling clay can also be made with this material in mixing it with the same liquid; it is said this would give very good results.

Mr. Richards described, at the meeting of the Iron and Steel Institute of London, an operation performed at Eston with Cleveland iron, of which the different phases had been studied chemically. The operation was performed on 6000 kilogrammes in a converter capable of containing eight tons. The pig iron had the following composition:

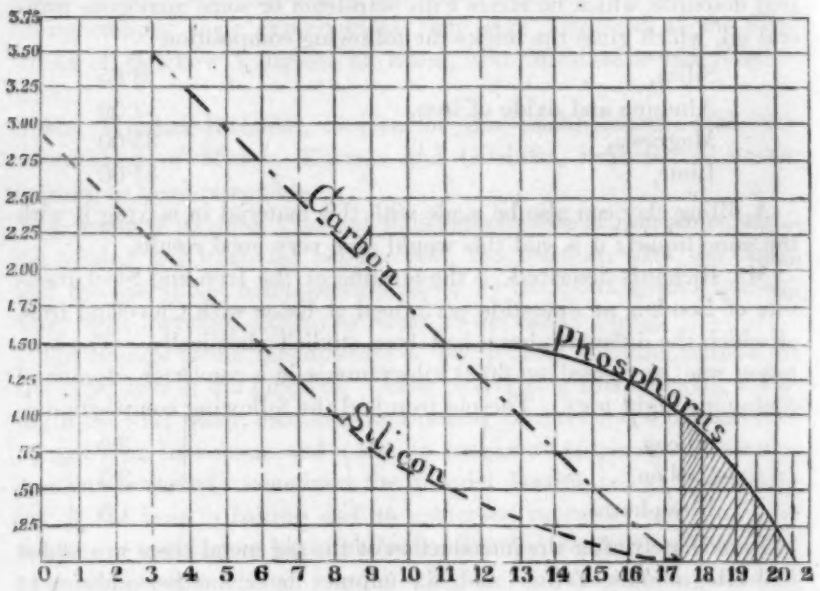
Silicon,	3·0
Carbon,	3·5
Phosphorus,	1·5

Immediately after the introduction of the pig metal there was added 500 kilogrammes of lime, and, six minutes later, another addition of 400 kilogrammes of lime and 300 of oxide of iron; this made a total of 1200 kilogrammes, or 20 per cent. of cold material.

The operation occupied 17 minutes, 9 for the first period and 8 for the second. A series of samples were taken and submitted to chemical analysis, resulting in a very interesting study of the changes of composition which occur during the refining. Mr. Richards constructed a diagram, the abscissas of which are the fractions of time occupied by the operation, and the ordinates are the different quantities of the elements contained in the metal.

It is seen that the phosphorus commences to disappear only after

the carbon is reduced to 1 per cent. and the silica to 0·3 per cent. The shaded portion of the diagram indicates the *overblowing;* this is the blowing which takes place after the total decarburation characterized by the fading away of the rays of the spectrum. It is a period during which oxide of iron is produced abundantly, and it is seen that it is also the time when the phosphorus is rapidly eliminated. In the case represented by the diagram the overblowing lasted three minutes, and in this short space of time two-thirds of the phosphorus was oxidized, whereas the other third had demanded twice this time to be scrorified.



Mr. Richards vouched for the fact that the metal in which the phosphorus had been reduced to less than a thousandth had a tensile strength of 70 kilogrammes per square millimetre, with an elongation of 25 per cent. in a length of 200 millimetres.

As to the waste, it oscillated between 18 and 20 per cent., varying with the dephosphorization which was attempted. When it was desired to have less than *a thousandth* of phosphorus in the metal, the waste amounted to 25 per cent. Ordinary pig metal, that of Cumberland for example, would give only 15 per cent.

The following description is of the two operations performed at Eston, May 13th, 1870, before the members of the Iron and Steel Institute.

First Operation.—They employed an 8-ton converter, lined with basic bricks, the composition of which has already been given; it was dolomite agglomerated with silicate of soda, a lining not very durable, perhaps, but which was preferable for the demonstration of the process.

Five tons and eight hundredweight of Cleveland iron was melted in a cupola, all the blast furnaces being stopped on account of a strike among the Durham miners. This iron had the following composition:

Silicon,	3·030
Carbon,	3·200
Sulphur,	0·030
Phosphorus,	1·800
Manganese,	0·450

Immediately after the introduction of the metal, there was thrown in from a barrow 1200 kilogrammes of a greyish material, in pieces about twice the size of a nut; it was the result of the roasting of a mixture of carbonate of lime and "blue billy." *

This material was cold, and had the following composition:

Silica,	1·00
Lime,	60·00
Peroxide of iron,	31·89
Carbonic acid,	6·40

This could not be prepared many days in advance, as it decrepitated by absorbing moisture from the atmosphere.

The operation, followed with the spectroscope, gave a period of 4 minutes and a second of 9½. After the falling of the flame there commenced an "overblowing" of nearly 3 minutes, and distributed about as follows:

1st. Overblowing of a minute and three-quarters; the converter was then turned down, and a specimen of the metal taken with a sort of ladle; this was cooled in a small ingot-mould, and then hammered into the form of a disk, one centimetre in thickness; it was recooled and broken under the stamper. The grain is coarse, flat, and bright, as

* Blue Billy is obtained in the treatment of calcined pyrites from which the copper has been extracted by the Henderson process.

that of very phosphoric iron. We will give later the amount of phosphorus contained (A^1).

2d. Overblowing of 45 seconds, and sample taken (A^2).

3d. Overblowing of 20 seconds, and sample taken (A^3).

All these successive attempts had prolonged the operation to about twenty minutes.

Next they proceeded to add 10 per cent. of spiegel, melted in the cupola and having the following composition:

Manganese,	17·000
Phosphorus,	0·163

This was introduced by degrees, on account of the violent reaction of the carbon of the spiegel with the oxide of iron in solution in the metal. It caused a greatly developed flame, and there is an overflow of a part of the slag.

	Phosphorus.
Pig metal,	1·800
A^1,	0·597
A^2,	0·360
A^3,	0·140
After spiegel,	0·235

This metal when rolled had the following composition:

Carbon,	0·330
Manganese,	0·213
Phosphorus,	0·235
Sulphur,	0·073

The ingots weighed from 600 to 700 kilogrammes. There were two roughed down, which behaved very well, and were rolled into small rails, having the weight of 20 kilogrammes per metre.

Second Operation.—The second operation was easy, compared with the first.

The charge of pig metal taken from a cupola was 6000 kilogrammes, and the addition of cold basic materials was 1200 kilogrammes. Observation with the spectroscope gave 7½ minutes for the first period, and as much more for the second. There were neither boiling nor violent projections, as in the first charge, due no doubt to the great capacity of the converter.

The overblowing, in which is included the taking of samples and all time lost, lasted nearly 20 minutes. Specimens B^1, B^2, etc., were

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taken, as in the first operation, and below are given the results of their analyses:

Overblowing.		Phosphorus.
Pig metal,		1·800
1 minute 30 seconds,	B^1,	0·830
30 "	B^2,	0·458
15 "	B^3,	0·334
15 "	B^4,	0·210
10 "	B^5,	0·140
After spiegel,		0·223

The addition of spiegel was 10 per cent. The reaction which followed was tumultuous, and the operation seemed to give a cold metal. The casting ladle became obstructed, and it was necessary to keep the tap-hole open with an iron rod. An ingot "scattered" some minutes after, which is characteristic of the overblown metal.

As to the rolled metal, it gave

Carbon,	0·171
Manganese,	0·160
Phosphorus,	0·223
Sulphur,	0·037
Silicon,	trace.

Two ingots were "roughed down"; one presented a great crack, which enlarged in finishing, but as the rail was 32 metres long, it could be cut up into useful pieces. After blooming, the other ingot showed numerous small cracks, indicating a red-short metal.

After these two operations, the condition of the lining seemed good; there could be noticed some cross-cracks, but the intensity of the radiation did not permit one to decide whether this was not the effect of the joints of the bricks. The bottom, where the tuyeres were replaced by holes cut in the lining, presented no cavities. It seemed but slightly worn, to judge of it by its flattening. The slag accompanying the metal of the last operation had about the following composition:

Silica,	21·50
Lime,	36·00
Magnesia,	4·94
Alumina,	1·30
Peroxide of iron,	6·09
Protoxide of iron,	9·94
Protoxide of manganese,	7·50
Phosphoric acid,	9·70

If this slag was homogenous, a simple calculation would show that the wear and tear of the lining had been 700 kilogrammes, because this slag contained nearly 5 per cent. of magnesia, which could only come from the lining, as there was no magnesium in the metal, and as the addition of 1200 kilogrammes of lime and oxide of iron contained only traces of magnesia. However this may be, there was a certain wear which is incontestable, and which only a successive series of operations could measure correctly.

If we consider the process of Messrs. Thomas and Gilchrist in its entirety, we see that from the first it is very satisfactory. What more simple in reality than to resolve the problem of dephosphorization, *without special apparatus, into absorbing the phosphorus by a basic addition destined to protect the lining, and to finish the operation in prolonging the blowing.*

If we study, on the contrary, the operations which we have just described, and compare them with the treatment of ordinary pure metal, we find;

That the capacity of the converters is utilized only in part, which is a cause of cooling, and a greater expense in erecting.

That by the repeated taking of samples, the operations are prolonged to at least double their length, which is a diminution of the production and a new cause of cooling.

That the waste is notably augmented.

That there is no character which announces the end of the dephosphorization, which necessitates numerous trials.

It seems difficult to obtain by this method a metal relatively carburetted.

Finally, *notwithstanding the large proportion of manganese introduced, the metal has a tendency to remain red-short, and consequently to roll irregularly.*

A last character, to which we will return later, is the *rephosphorization of the metal after the addition of the spiegel.* The amount of phosphorus in the metal, after having been reduced to 0·140, rises again to 0·235 and 0·223. This is a very curious phenomenon that the English metallurgists explained by a reducing action of the manganese exerted on the phosphate products, and of which the slag contained quite a large proportion. If the phosphorus is in the slag, in the state of phosphate of lime, of manganese, or of alumina, no such reaction seems possible. If the phosphorus is in the state of phosphate of iron, it would be necessary that a phosphuret of iron or of

manganese be produced, going over again into the metal, which also seems to us improbable.

Ponsard Furnace-Converter.—This is an apparatus which partakes of the characteristics of both the Bessemer converter and the Martin-Siemens furnace. In a certain position of the movable bed-plate there can be placed tuyeres which blow air into the metallic bath.

Attempts at dephosphorization have been made with this apparatus at Thy-le-Chateau, near Charleroi. With a basic lining, analogous to that of Messrs. Thomas and Gilchrist, they would have been able to have produced steel from very phosphoric iron. But these trials were not very conclusive, the heat having been insufficient. New experiments ought to be undertaken before long at Creil. They should employ simultaneously the Ponsard recuperator and the Siemens regenerator, which alone can lead to a very instructive and interesting comparison.

It remains for us now to present some general observations on the chemical phenomena which are met in the several methods of dephosphorization of which we have spoken.

There is one fact which strikes us first. It is that, in furnace purifications, the dephosphorization takes place without any important elimination of the carbon; with the Bessemer process, on the contrary, there is no notable dephosphorization until after the carbon has been much reduced, and the dephosphorization is completed only after total decarburation.

How reconcile these two contradictory phenomena?

The following is the explanation given by M. Pourcel, in charge of the steel works at Terre-Noire, in a communication which he made June 7th, 1879, to the Society of Mineral Industries of Saint Etienne.

The carbonic oxide exerts an energetic reducing action on the phosphate of iron. Under its action there is formed phosphuret of iron, which dissolves in the metal or steel surrounding it. This reducing action ought, without any doubt, to increase with the temperature.

In the purifying processes of Mr. Bell and of Messrs. Narjes and Bender the oxidizing action of the peroxide of iron exerts itself on the silicon and phosphorus from the very first. There is formed silica and phosphoric acid, which combine with the oxides of iron present. As there is little or no carbon burnt, there is no carbonic oxide produced; the phosphate of iron formed has not then an opportunity to be reduced,

since the operation is stopped when the disengagement of gas commences. It is the presence of the silicon which prevents the combustion of the carbon, the same as in the Bessemer process. Further, as long as there is silicon present the carbonic oxide cannot remain in solution in the metal; it is decomposed, as shown in the theory of the manufacture of blister-steel.

One can even go further, and say that if there had not been any silicon present, these purifying processes could not have been operated unless a strong proportion of manganese protected the carbon against oxidation.

In the Thomas and Gilchrist process, on the contrary, we see the dephosphorization commences only when the proportion of carbon is below one per cent., and is not finished until after total decarburation. The oxide of iron produced then exerts itself exclusively on the phosphorus without being influenced by the reducing action of the carbonic oxide.

In this process what then is the effect of the basic lining and the additions of lime mixed with oxide of iron? The English metallurgists pretend that they are destined to saturate the silica produced and to permit the production of an earthy phosphate (lime, alumina, or manganese). They affirm, then, that the phosphorus is not in the slag in the state of phosphate of iron. The grounds on which they base their conclusions are the following:

The hydrosulphate of ammonia, while cold, transforms the phosphate of iron into sulphuret of iron and phosphate of ammonia. The chloride of sodium, when hot, transforms the phosphate of iron into chloride of iron and phosphate of soda. They have not succeeded in producing any of these reactions with the slags of their operations; but with weak acids they have been able to dissolve the phosphate of lime.

Is this method of reasoning, which takes no account of the disturbing action of the silica, unassailable? Are we not in presence of a silico-phosphate of iron, which resists the first reagents and succumbs to the more energetic action of acids?

If, on the contrary, we consider the decided development of carbonic oxide after the addition of the spiegel, and which does not appear at the mouth of the converter until after having passed through this thick bed of slag, containing, as we have seen, nearly ten per cent. of phosphoric acid, have we not there an energetic reducing agent which ought

to play an important part? It is certainly this carbonic oxide which makes the phosphorus, removed from the slag, pass back into the metal. But this carbonic oxide, as we said in commencing, exerts no action on the phosphates of lime, of alumina or of magnesia; it is then the phosphate of iron which it reduces.

The phenomena is perhaps complex. It is possible that earthy phosphates are formed at the commencement of the operation, but it seems difficult to admit that, in the overblowing, the oxide of iron in the nascent state does not combine more or less with the phosphoric acid produced.

Monsieur Pourcel, in trying to connect all these methods of purification, could not see why, during the first period of the Thomas and Gilchrist process, the phosphorus should not be eliminated just the same as in the process of Mr. Bell and of Messrs. Narjes and Bender. It seemed to him that the phosphorus curve ought to sink toward the axis of abscissas during the combustion of the silicon, in order to rise afterwards during the combustion of the carbon, on account of the reducing effect of the carbonic oxide.

This manner of reasoning seems very logical, and would merit being verified by a special experiment, which would well repay such trouble.

There is, nevertheless, a certain difference between the purifying processes of which we have spoken and the first period of the Thomas and Gilchrist process. In the first case we have an oxidizing action, which is perhaps more energetic on account of the presence in excess of peroxide of iron, whereas in the Bessemer process the oxygen blast exerts itself on the silicon, perhaps, before acting on the phosphorus. The straight line of the phosphorus, in the diagram of Mr. Richards, is not a proof that dephosphorization has not taken place from the commencement; indeed, it would have been possible to have made only a quantitative analysis after the first period, when all the phosphorus oxidized would have been reduced, and to have concluded from this the absence of dephosphorization. The straight line of the carbon is quite hypothetical; that of phosphorus is perhaps as much so. It is, indeed, impossible that the proportion of carbon should remain constant, and this for two reasons: 1st. As there is elimination of silicon and a certain production of oxide of iron, the mass treated has diminished, the per cent. of carbon ought, then, to be augmented. 2d. The first period of all Bessemer operations is accompanied by reddish sparks, which are more or less abundant, but which are probably

graphite partially burnt. But, after all, two analyses of Bessemer operations performed in Germany prove this augmentation of the carbon: according to Kessler, after 4 minutes the carbon passes in one operation from 3·58 to 3·79, and in another from 3·03 to 3·17.

To conclude, we say, 1st. *That the dephosphorization of pig iron by a purifying process in a furnace seems to us practically demonstrated.*

2d. *That with the Bessemer process the manufacture of steel from very phosphoric pig iron is a fact perfectly established and complete from a scientific point of view.*

There remain practical difficulties, that the authors of the process recognize themselves, and they seek to conquer them by continuing their experiments; but the moment does not seem to be very distant when all which still embarrasses the process will be completely resolved.

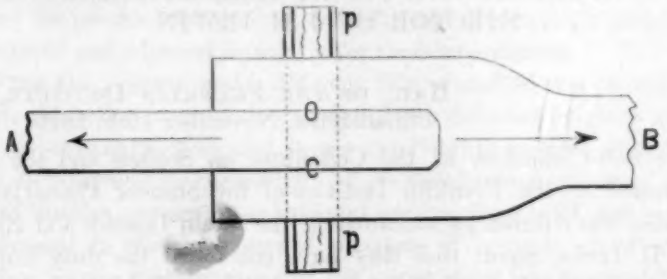
Nutritious Ferns.—The dwellers on the argillaceous mountains of Japan derive most of their food from a variety of ferns, which they call *warabi*. In spring they eat the young leaves; later in the season they feed on the starch which they extract from the roots. In extracting the starch, the roots are carefully washed in order to remove all dirt, then crushed by mallets, and the pulp stirred in reservoirs of water. The water is then drawn into other reservoirs to settle, depositing about 15 pounds of starch for every 100 pounds of roots. In order to secure the reproduction of the ferns, the natives often burn the herbage and brush-wood that spring up under the shade of the oaks and chestnuts. Vast tracts have been devastated by this deplorable practice.—*Les Mondes.* C.

Hunting by Electricity.—A new application of the Ruhmkorff coil has been made in the neighborhood of Marseilles. Instead of using bird-lime on trees which are frequented by birds of passage, a copper wire is wound around the trunk and a decoy attached to a neighboring staff. When a numerous flock has been attracted by the decoy, a shock is sent by the commutator, and they are more surely stunned than by a rifle. Experiments of a similar kind have also been made by M. Dalmas upon the vines at his country-seat, and powerful shocks are said to have destroyed the parasites together with their eggs. If this statement is confirmed, the ingenious inventor may reasonably expect the prize of 100,000 francs, which has been offered for the destruction of the phylloxera.—*Les Mondes.* C.

SHEARING STRENGTHS OF SOME AMERICAN WOODS.

By JOHN C. TRAUTWINE, C.E.

Notwithstanding the common use of wood for pins, or treenails, no experiments that I know of, except one or two isolated ones, and they imperfect, have been tried for determining the extent of its reliability for this purpose. With a view to supplying this deficiency in some measure, I have recently tested several of our American woods, in the shape of cylindrical pins ·64 of an inch (or full $\frac{5}{8}$ inch) in diameter. I used one of Messrs. Riehlé's well-known and accurate testing machines, in connection with an iron holder, shown in the figure, and through a cylindrical hole in which the closely fitting wooden pin, *pp*, to be tested was placed. The two parts *A* and *B* of this holder being then pulled in opposite directions, it is plain that the pin can yield only by direct shearing at *O* and *C*.



Two specimens of each were tried. Where their difference did not exceed 10 per cent., the mean is given. Greater differences must of course be of frequent occurrence, even in good sound specimens. All the specimens were fairly seasoned and without defects. The central pieces sheared off were $\frac{5}{8}$ inch long; The single circular area of each pin was ·322 of a square inch; and that of the two areas that were sheared at once ·644 of a square inch; and since $·644 \times 1·55 = 1$ square inch, it follows that if the results in the table be divided by 1·55, the quotient will be the actual double-shearing strength found for each pin of full $\frac{5}{8}$ inch diameter.

The following table gives the results in pounds per square inch of total sheared area:

	Pounds per sq. inch.		Pounds per sq. inch.
Ash,	6280	Locust,	7176
Beech,	5223	Maple,	6355
Birch,	5595	Oak, white,	4425
Cedar, white,	1372 to 1519	" live,	8480
" Central America,	3410	Pine, white,	2480
Cherry,	2945	" yellow, northern,	4340
Chestnut,	1535	" " southern	5735
Dogwood,	6510	" " very resinous,	5053
Ebony,	7750	Poplar,	4418
Gum,	5890	Spruce,	3255
Hemlock,	2750	Walnut, black,	4728
Hickory,	6045 to 7285	" common,	2830

REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS ON THE STEAM INJECTOR AND EJECTOR OF J. H. IRWIN.

HALL OF THE FRANKLIN INSTITUTE,
Philadelphia, November 15th, 1879.

The Sub-Committee of the Committee on Science and the Arts, constituted by the Franklin Institute of the State of Pennsylvania, to whom was referred for examination the Steam Injector and Ejector of J. H. Irwin, report that they have concluded the duty imposed upon them, and submit the following as the result of that investigation:

The experiments were conducted at the country place of Mr. Irwin, situated at Morton, about nine miles out on the West Chester and Philadelphia Railroad, where were found all the facilities needed for such an undertaking, there being an experimental machine shop, where the instruments experimented with were made, fitted up with all the appliances required, and workmen who understood the proper fitting up of the proper instruments and their connections.

The experiments occupied the committee five days' close application of about seven hours each, beside which one of the committee was occupied an additional week in preparing and arrranging for the experiments.

Manner of Conducting the Experiments.

The water supply for the injectors was received in a large circular wooden tank, capable of holding 400 gallons, mounted on a large platform scale, having the capacity to weigh 6000 lbs. The delivered water from the injector was conducted, by wrought iron pipe, into another tank, situated on a similar platform scale. A chemical thermometer, Fahrenheit's scale, was kept immersed in the feed water tank for the purpose of observation; the delivered water was tested, as it left the injector, and as close to it as practicable, by a similar thermometer, fitted into an ordinary *tee* steam fitting by passing through a cork, the bulb of the instrument protruding into the current fluid.

A steam pressure gauge was arranged on the steam supply pipe, close to the injector, and a water pressure gauge between the thermometer *tee* and the injector, with a globe valve just beyond the gauge, to throttle the water discharge and regulate the delivery pressure, which in the first series of these experiments was adjusted to equal the pressure of the steam, in effect the same as forcing the water into the boiler; the gauges used were of Schaeffer and Budenberg's make, and were tested and adjusted especially for these experiments.

To test the injector under different lifts, a scaffold was erected just outside the boiler room, with stagings at two different heights; and in order to economize time and lessen the liability to error from leaky joints, in re-arranging the position of *a single* instrument, three injectors, of similar pattern, were taken at random from a lot, and erected permanently in the three several positions of altitude, all of which, however, gave a further range of lift as the water was lowered in the feed tank.

A Wiegand Boiler was used to furnish steam, having 9·625 square feet of grate surface, and to record the pressure of the steam was used an excellent mercury gauge made by David Lithgow, of Philadelphia.

A steam valve was fitted to the steam pipe outside, close to the injector, for the purpose of regulating the amount of steam admitted to the instrument, but was not used, except wide open, in the first series of experiments, the indications all being taken from the mercury gauge attached to the boiler: across the face of which was arranged a metal slide, which was set in a line with the pressure required, and the engineer kept the mercury *on the line of sight* by opening, closing and regulating the draft by the furnace door, throughout the several

experiments in an admirable manner, and practically without any sensible variation in the pressure of the steam.

Manner of Recording the Experiments.

The manipulation of the injectors was done by the inventor, Mr. Irwin; the members of the committee had, individually, a separate duty assigned. One was stationed at the feed water scales, another at the delivered water scales; one observed the temperature of the feed water and took the height of the lift immediately preceding and at the close of each experiment; another took the temperature of the delivered water and noted the steam and water pressures, while duplicate records were kept by two different individuals, as a check upon each other.

Each experiment was started by the operator on the injector starting the instrument and adjusting it in proper running order for the work to be performed. When brought to this condition the word *now* was given, at which moment the weights on the two scales were taken, and the readings of the different gauges, thermometers and instruments of measurement were noted, and the experiment proceeded, for generally fifteen minutes. When the time was up by the watch the word *now* was again repeated, when instantly the weights and readings of the several instruments were again taken, reduced to the mean, and called off for record, warning being invariably given just before beginning and ending of each experiment. In this way there was no confusion, the duty of each was simple, and the posting perfect, while the manner of arriving at the results is eminently practical. Taking the first experiment as an exponent of them all, we find that 471·5 lbs. of water had been taken from the feed water tank, and 492 lbs. had been discharged into the delivery water tank, in fifteen minutes, it is obvious the difference, 20·5 lbs., must be the weight of steam used in effecting the trnsfer. In this way there are no doubtful calculations to be performed; not only has the water passed through the instrument been weighed, but the amount of steam used to perform the work has been accurately weighed and ascertained; the subsequent calculations made, and recorded in the appended tabular list of these experiments, are of a very simple nature, although requiring a considerable amount of arithmetical calculation. Each one furnishes the evidence to detect any error which may have crept in during the taking of any individual experiment, for if the units of heat in the feed

water lifted per pound of steam at any given pressure be taken from the total units of heat found in the water delivered, the difference would show the units of heat pertaining to that steam, and the difference between the latter quantity and the theoretical heat in one pound of steam at the given pressure, taken from Regnault's tables, furnishes the error of the experiment, under the supposition that dry, saturated steam was used and losses from radiation, &c., omitted.

This check, showing the error of each experiment, is shown in columns 16, 17, 18, 19 and 20 of the first series of experiments.

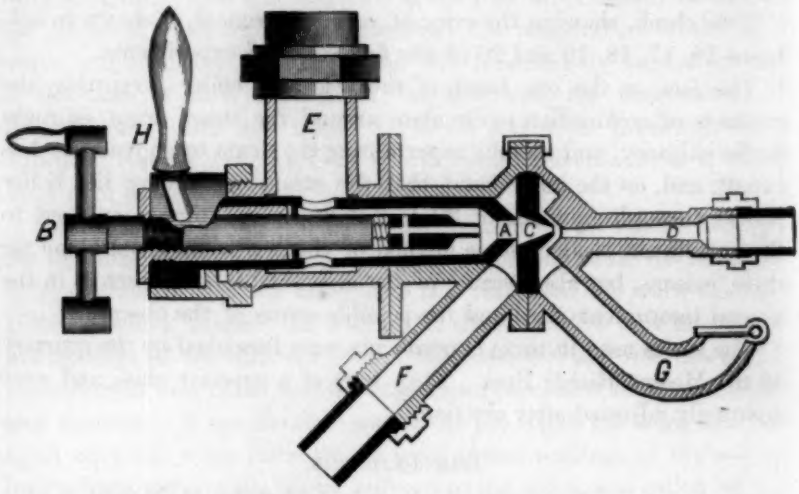
The fact, on the one hand, of the Wiegand boiler permitting the products of combustion to circulate around the steam drum, en route to the chimney, and thereby superheating the steam to a greater or less extent, and, on the other hand, that the steam on leaving the boiler passed through upwards of 30 feet of uncovered piping exposed to the outside air, renders some method of check necessary, not alone for these reasons, but also because of the unavoidable small errors in the several instruments used and the possible errors of the observers.

The scales used in these experiments were furnished by the courtesy of the Messrs. Riehlé Bros. They were of a superior class, and were accurately adjusted after erection.

The Injector,

As made in accordance with the laws laid down by Mr. Irwin, is of a general nature. The whole of the tabulated experiments shown in series 1, 2 and 3, ranging from where 105 pounds of steam pressure above the atmosphere was used down to 15 inches of vacuum, with the instrument still working, and where an augmented pressure of 330 pounds was obtained by 90 pounds of steam down to 10 inches of vacuum, where an augmented pressure of 10 pounds was gained; where 1 pound of steam forced against a pressure of 25 pounds, and 1 pound of vacuum against 15 pounds, including the hot water experiments, running up to where feed water of 122 degrees Fahr. was lifted 19 inches and forced by 30 pounds steam against an equally resisting pressure, and also where the water was lifted 21 feet with 40 pounds of steam against 60 pounds pressure, were performed *by the same instrument*, without a particle of change or alteration. In all these varied tests the instrument generally responded promptly, and ran through the allotted time, usually 15 minutes, without readjustment, and it was remarkable to observe how stationary all the gauges and thermometers remained, having once settled down to the work before them.

The law governing the economical action of injectors, as enunciated by Mr. Irwin, may be briefly stated to require the employment of certain angles and set dimensions of the interior working parts, which have been arrived at after a series of numberless experiments extending over a period of 6 years, of which the following are the most important:



A is the steam jet which is adjusted by means of the screw spindle and crank *B*; this spindle contains a small starting jet

C is the combining cone in which the steam is condensed, and the issuing stream of water is received by the receiving tube *D*.

E is the steam supply pipe; *F* the water supply pipe, and *G* the overflow.

The supply of water is regulated by means of the oblique slot and handle *H*.

Taking the lesser diameter of the combining cone as the standard of measurement of the instrument, which call . .	1
The larger diameter and length of combining cone, . .	= 4
The diameter and length of jet opening in steam cone, .	= 2
Smaller diameter of receiving cone, ...	= 1
Larger " " "	= 2
Length " "	= 16
Diameter of starting steam jet, ...	=0·5

There are also some other determined dimensions of universal application, a full explanation of which will be gathered from a perusal of

the patents appended. One peculiarity may be mentioned. The water supply pipe and overflow are set at an angle of 45° to the axis of the instrument, which, it is claimed, materially increases the power of augmentation. Permitting the free entrance of the atmospheric air at and through the overflow, it is also maintained, gives a clear gain to the extent of one atmosphere in the same direction. This could be practically tested by placing the thumb over the orifice of the overflow, when the index of the pressure gauge would immediately fall back about 15 pounds, and advance again to the same extent by the removal of the obstruction. A way of proving the correctness of this assumption was to turn on steam enough to work the injector against any determined pressure when the overflow was closed, then by opening it a certain amount of steam could be shut off, producing the same pressure on the gauge. The steam so shut off was undoubtedly saved (see experiment *A*).

The dimensions of the instruments experimented with were:

Lesser diameter of combining cone and receiving cone, .	$\frac{3}{16}$ inch
Diameter and length of jet orifice in steam cone, .	$\frac{3}{8}$ "
Diameter of starting steam jet, . . .	$\frac{3}{32}$ "

The other dimensions may be ascertained by recurring to the proportional dimensions above laid down.

The Result of the Experiments

Would lead to the conclusion that the information gained in regard to this injector is highly important in the cause of science, and that Mr. Irwin has contributed a valuable improvement in the manner of constructing injectors, increasing their power of augmentation to above twice that of the pressure of steam used for practical working without waste, and about four times with waste at the overflow, as will be seen by taking the average of the experiments shown in the 2d Series, which seem to carry out a general law, that *the lower the steam employed, the higher could the proportional augmentation of pressure be carried.*

In the first series of experiments, column 20 shows the percentage of error of each experiment. The method of checking the experiments can be shown algebraically as follows:

Let R = the total heat of 1 pound of steam for the observed pressure, taken from Regnault's tables;

D = the specific heat of the delivered water for the observed temperature;

X = the weight of feed water delivered per pound of steam;

F = the specific heat of the feed water for its observed temperature;

And E = the error of the experiment.

Then, if we neglect the losses of heat due to radiation, and the small amount of work done in lifting the water to the injector, and consider that the friction of the water in forcing its way through the throttle valve converts the work done there into heat,

we have $$(1 + X)\,D - XF = R + E,$$

or, $$E = (1 + X)\,D - XF - R = D - R + (D - F)\,X.$$

If, further, we assume the error to be equal to zero, we have from the preceding equation $X = \frac{R - D}{D - F}$, which gives us a means of determining the weight of water fed per pound of steam with sufficient accuracy, when the three terms:

1. The steam pressure; 2. the temperature of the feed water; 3. the temperature of the delivered water, are known.

Taking for example experiment 3 of the First Series, we have

$$R = 1165{\cdot}6 \text{ heat units.}$$
$$D = 110{\cdot}267.$$
$$F = 30{\cdot}5.$$

$$X = \frac{R - D}{D - F} = \frac{1165\,6 - 110.267}{110\,3 - 30{\cdot}5} = \frac{1055{\cdot}3}{79{\cdot}8} = 13{\cdot}23 \text{ pounds,}$$

a quantity slightly less than the observed result, but only noticeably less because the experiment shows an error in excess.

The percentage of error is found by dividing the ascertained error (E) by the total quantity of heat in one pound of steam plus the heat of the delivered feed water $= [(1 + X)\,D]$.

The horse power of this injector can be determined with sufficient approximation from column 14, First Series, one pound of water per minute being, with sufficient margin in excess, the supply of water required per horse power.

The range of the injector is shown in a few cases in column 15, First Series, and is a criterion of its adaptability to the varying supply often demanded of an injector.

The committee were limited to 105 pounds steam pressure, as the boiler was not in a condition to use anything higher.

EXPERIMENT *A*.

Steam Press.	Water Press.	Temp. Delivery.	
90	93	138°	Overflow open.
90	83	136°	Overflow shut.

Opening the overflow again, the pressure rose to 93 pounds. Some steam was then shut off, reducing the water pressure to 83 pounds, the same as indicated with the overflow shut, when the temperature of the delivered water fell to 127°. This experiment was several times repeated, with the same general result. The experiments upon high temperatures of feed water not presenting as high a range as in the case of other injectors, certain alterations in the interior angles of the instrument were made, increasing the diameter and length of the combining and receiving cones, doubling their proportions, with an advantage in point of taking hotter water to the detriment of the other characteristics of the instrument, as will be seen by the following:

EXPERIMENT *B*.

Steam.	Temp.	Head.	
80	120°	13 inches	Water forced into boiler.
85	134°	10 "	There being a slight overflow.
95	144°	7 "	

The temperature of the feed water was now run down to 74°, in order to test the power of augmentation, resulting as follows:

EXPERIMENT *C*.

The instrument would just take water at	35 pounds.
Commenced to overflow at	70 "
Broke at	75 "
With steam at	90 "
Overflow at	125 "
Broke at	150 "

The duty of the injector, though comparatively unimportant, has been computed, and is shown in columns 21, 22 and 23, First Series. Column 21 contains the head, and consists of the lift of the injector plus the resisting pressure of the water in pounds multiplied by 2·3 feet

Column 22 contains the duty per pound of steam.

Letting h = the head in feet, computed as above, we have

$$h \times (1 + X) = \text{duty per pound of steam.}$$

Column 23 contains the duty, as ordinarily expressed, for pumping engines per 100 pounds of coal, estimated as capable of making 900 pounds of steam, upon the basis of an evaporation of 9 pounds of water per pound of coal.

All of which is respectfully submitted.

WASHINGTON JONES,
W. BARNET LE VAN,
TINIUS OLSEN,
WILLIAM M. HENDERSON,
WM. D. MARKS, *Chairman.*

Approved:

J. B. BURLEIGH, *Chairman pro tem.*

January 7th, 1880.

Experiments upon Human Heat.—Hirn has supplemented his brilliant thermo-dynamic experiments by an application of his method to the human organism, in order to ascertain its mechanical equivalent. He finds that in the normal condition, while the heat of the body is increasing or decreasing, every 425 kilogrammetres (3074·084 foot-pounds) of work costs or brings to the organism a unit of heat. By comparing the heat which really appears or disappears with that which ought to appear or disappear, we can study what is going on in our bodies, and how they are modified by the conditions in which they are placed. The laws of mechanical physics may thus teach us how and how much our organism differs from an ordinary machine.—*Comptes Rendus.* C.

Prediction of Harvests.—Hervé Mangon has examined the climatological conditions of the years from 1869 to 1879, in Normandy, and their influence upon the ripening of the crops. He gives three tables of the amount of heat received by different grains between planting and harvesting, and draws two important practical conclusions: 1. In a mild and regular climate it is generally desirable to sow the crops early in the fall. 2. By observing each year the amount of heat received subsequently to planting, and by consulting properly prepared tables, it is possible to calculate a month or six weeks in advance the time of harvest. In his own tables he fixed upon 6°C. (42·8°F.) as the growing limit, and recorded the number of degrees at each observation above that limit.—*Comptes Rendus.* C.

Tabulated report of experiments made by Sub Committe 1163 on John H Towns Steam Injector and Ejector. being a portion of the Report first read by the Committe of Science and Arts of the Franklin Institute Dec 3rd 1879

Experiments upon the Towne Steam Injector. by the sub-committee of Science and Arts of the Franklin Institute. First Series.

	Observed Data.												Delivery			Check				Results			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
	Number of Experiment	Duration of Experiment	Height of Barometer	Temperature of Atmosphere	Steam pressure by Gauge	Water pressure by Gauge	Steam used	Feed water delivered	Temp. of Feed water	Water delivered per hour	Temp. of Delivered water	Temp. of Injector & Pipe	Water delivered per lb. of Steam	Water delivered per lb. of Combustible	Ratio	Units of heat in delivered water	Units of heat in feed water	Units of heat in steam used	Error of Experiment	Percentage of Error	Total heat	Units done in Lifting and giving Velocity to Stream	Units of Injector & Pipe
		Minutes	Inches	Fahr.	Lbs. per sq. inch	Lbs. per sq. inch	Lbs.	Lbs.	Deg. Fahr.	Lbs.	Deg. Fahr.	Deg. Fahr.	Lbs.	Lbs.		Heat Units	Heat Units	Heat Units	Heat Units	Per Cent	Heat Units	Foot Lbs.	Heat Units
1	15	29.95	75°	15	15	205	471.5	62.5°	492	104°	7.'66	23	31.43			1728.	701.5	1026.5	—132.	7⅞	42	1008	907.200.
2	5	29.92	80°	15	15	5.	170	62.5°	176	98.5°	8.07⅝	34.	34.			2223.5	1027.	1290.5	+137.	5¾%	42.5	1487.5	1338.750
3	15	29.93	78°	30	30	52.75	705.75	62.5°	768.5	142°	8.8¼	13.37	49.05			1544.5	407.5	1176.7	+14.1	0.7%	77.75	1117.26	1.005.530
4	10	29.92	62°	30	30	15	373.5	64.5°	388.5	113°	9.5⅝	24.9	37.35			2101.	810.	1291.	+126.	6%	76.5	2013.15	1.829.835
5	15	29.87	76°	45	45	32	674.	68°	706.	124°	7.1¼	21.06	44.93			2024.7	749.2	1274.5	+103.	5%	110.05	2440.94	2.190.845
6	10	29.87	75°	45	45	23	411.	68°	424	126°	7.9¾	17.67	44.10			1777.3	643.7	1133.6	—2.5	2.1%	111.31	2100.42	1.890.377
7	10	29.87	76°	60	60	28.5	496.5	68°	521.	130°	9.02	19.54	49.65			2024.2	703.2	1320.4	+144.9	7.1%	147.	3019.38	2.717.442
8	15	29.87	72°	75	75	45.	779.	60.5°	824	124°	9.1¾	17.31	17.93			1067.8	493.5	1194.	+14.6	0.9%	16.66	3326.17	2.993.574
9	15	29.95	64°	90	90	59	786.5	69.5°	845.5	140°	7.1¾	13.24	52.43			1625.	500.5	1124.5	—59.5	3.6%	214.16	3071.05	2.763.948
10	15	29.94	65°	90	90	53.75	466.25	69°	520	182°	7.9¾	8.67	31.05		0.89	1455.7	320.9	1134.8	—15.2	3.3%	214.51	3077.26	1.909.482
11	15	29.93	64°	105	105	61.5	779.	69°	840.5	150°	8.6¾	12.66	17.93			1616.	456.	1160.	—26.	1.6%	260.06	3415.84	3.074.257
12	15	29.95	66°	105	105	61.75	488.25	69°	541.	174°	9.2.5	7.9	32.06		0.62	1424.	284.	1164.	—22.	1.9%	250.70	2201.52	2.001.187
13	15	29.91	64°	30	30	20.	542.25	68°	572.25	132°	14.8¾	15.07	36.15			1736.4	660.9	1062.5	—73.	4.5%	82.75	1647.11	1.483.440
14	15	29.92	65°	60	60	36.5	625.	67.5°	661.1	133°	10.3¾	17.12	41.66			1832.7	607.7	1226.	+50.3	2.7%	152.22	2778.26	2.500.575
15	15	29.97	57°	60	60	38.5	602.5	63.5°	641.	132°	14.4½	13.65	40.16		0.96	1668.3	492.1	1175.+	—.05	0.0	182.20	2586.62	2.328.966
16	10	29.97	56°	90	90	39.	369.5	64°	398.5	167°	14.11.	9.22	36.95			1284.1	295.1	1089.	—92.9	6.5%	221.92	2268.02	2.041.218
17	10	29.98	55°	90	90	37.6	411.	63°	448.5	180°	15.4½	10.96	41.10		0.87	1416.9	341.5	1075.4	—102.5	7.6%	222.25	2619.30	2.398.537
18	15	30.01	50°	90	90	62.5	497.5	46.5°	1061	116°	61 head.	15.71	66.5			1405.8	274.9	1130.9	—52.	3.7%	206.46	3449.96	3.104.964.
19	15	30.60	48°	90	90	65	422.	64.5°	497.	200°	mixed	66.5	21.8		0.43	1290.8	162.9	1127.9	—55.	4.3%	206.06	1576.26	1.418.723
20	15	30.60	49°	60	60	51.	835	55°	886	114°	Slip	16.27	51.66			1424.9	376.	1053.9	—1215	8.5%	138.28	2401.40	2.16 1.262

Col. 15 is found by dividing the number of lbs of Water and Steam delivered, by lbs of Steam used. & X by Temperature of delivered water above 32°

Column 17 is found by multiplying the number of lbs of Water delivered by the Temperature of feed water above 32°.

Column 18 is found by subtracting the one from the other. Column 19 is found by comparing column 18. with the corresponding theoretical heats as given in Regnault's Tables.

Second Series of Experiments

Williams Trials — Watts Trials

Third Series of Experiments

8	15	29.87	72°	75	76	45.	779.	60.5°	834	124°	9.178	17.31	57.93	0.59	1667.5	493.5	1194.	+146	0.9%	15166	3326.19	2.593	674
9	15	29.95	64°	90	90	59	786.5	69.6°	846.5	145°	7.178	13.24	42.43		1625.	500.5	1124.5	-56.	3.6%	12616	3071.85	2.763	648
10	15	29.94	65°	90	90	53.75	466.25	69 °	520	182°	7.974	8.67	31.05		1455.7	320.9	1134.8	-66.	5.3%	11451	2077.21	1.809	482
11	15	29.93	64°	105	105	61.5	779.	68 °	840.5	160°	8.674	12.66	17.93	0.62	1616.	456.	1160.	-26.	1.6%	12006	3415.51	2.074	237.
12	15	29.95	66°	105	103	61.75	480.25	68 °	541.	174°	9.25	7.9	3206		1214	284	1164	-22.	1.9%	12071	2211.52	2.009	187
13	15	29.91	64°	30	30	20.	542.25	68 °	572.25	122°	14.876	15.07	36.15		1738.4	610.9	1127.5	-78.	4.5%	12375	1497.11	1.483	400
14	15	29.92	63°	60	60	36.5	625.	67.5°	661.5	133°	10.376	17.12	41.66		1632.7	607.7	1225	+203	2.7%	13221	2778.24	2.260	505
15	15	29.97	57°	60	60	38.5	602.5	63.5°	641.	132°	14.44	15.65	40.16	0.96	1661.5	493.1	1175+	-25	0.0	15221	2836.61	2.282	964
16	10	29.97	56°	90	90	39.	369.5	64 °	398.5	167°	14.11	9.22	35.95		1384.1	295.1	1089.	-94	6.5%	22142	2280.02	2.041	219
17	10	29.98	55°	90	90	37.6	411.	63 °	448.6	160°	15.44	10.96	41.10	0.87	1416.9	341.5	1075.4	-105	7.6%	22225	2649.30	2.393	378
18	15	30.61	50°	90	90	62.5	997.5	46.5°	1061.	116°	6.44	15.71	66.5		1405.8	274.9	1130.9	-52.	3.7%	20648	3449.94	3.104	961.
19	15	30.60	45°	90	90	65	432.	66.5°	497.	200°	W.Wind	6.65	21.8	0.43	1290.8	162.9	1127.9	-55.	4.3%	20666	1676.36	1.418	723
20	15	30.60	49°	60	60	51.	835	55 °	886	114°	S.W.E.	16.27	55.66		1429.9	376.	1053.9	-125	8.5%	13820	2401.40	2.16	1262

Note! Column 16 is found by dividing the number of lbs of Water delivered by the steam used. by X by the temperature of delivered water above 32°

Column 17 is found by multiplying the number of lbs of Water delivered by the temperature of feed water above 32°.

Column 18 is found by subtracting the one from the other. Column 19 is found by comparing column 18. with the corresponding theoretical heat as given in Regnaults Tables.

Second Series of Experiments

1	42°	0.11"	105	190	1.81	165°	345	3.29	184°	82°	307		1	7½	15	0.0	68°					
2	48°	1.15"	95	175	1.84	180°	325	3.30	184°	"	"		2	8½	15	0.0	70°					
3	48°	1.4"	85	165	1.94	196°	320	3.77	198°	"	"		3	16	16	0.25"	77°					
4	45°	1.85"	75	160	2.13	178°	275	3.66	180°	"	"		4	20	20	0.62"	80°					
5	48°	1.7"	65	160	2.21	166°	255	3.92	166°	"	"		5	20	20	0.62"	84°					
6	64°	0.7"	55	123	2.24	151°	200	3.63	154°	"	"		6	25	25	0.9"	98°					

4	45°	1.52	75	160	2.13	178°	275	3.66	180°	"	"
5	43°	1.7	64	140	2.21	168°	255	3.92	166°	"	"
6	64°	0.7	42	123	2.24	147°	200	3.63	154°	"	"
7	44°	1.22	45	90	2.00	116°	140	4.22	140°	"	"
8	36°	1.52	35	80	2.29	120°	125	3.43	125°	"	"
9	36°	1.11	25	60	2.40	144°	106	4.24	135°	"	"
10	40°	1.8	16	40	2.50	92°				"	"
11	38°	1.10	14	30	2.14	83°				"	"
12.	36	1.11	10	25	2.40	85°				"	80.65

4	20	20	0.62	80°	
5	20	20	0.63	84°	
6	25	25	0.9	98°	
7	30	30	1.2	100°	
8	30	80	1.3	108°	
9	45	45	1.7	122°	

Note. The injector refused to work at higher pressures than the 2nd & 3rd in practice of feed water ends broke at the pressures and temperatures given in the Table. The calculated water pressures are absolute pressures.

Note. The Augmenter pressures in these experiments were taken while the injector was working steadily, but would have broken with a slight increase of pressure.

The steam & water pressures are the pressures above a perfect vacuum & are computed by adding 15 lbs to the gauge pressures.

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MINERALOGICAL NOTES.

By Wm. H. Wahl, Ph.D.

In *mineralogy* the usual amount of activity has been displayed during the past year, though the record is not so interesting as that of the preceding year. In chemical mineralogy especially there have been some highly important researches that have added a number of new elements to science. The mineral samarskite, which has already yielded two new elements, phillipium and decipium, is affirmed by Boisbaudran to contain still another, to which he has given the name of *samarium;* while gadolinite, which in 1878 yielded ytterbium to Marignac, contains, according to Nilson, a new element, *scandium.* The same new radical is affirmed to have been detected in yttrotitanite, and Clève, who has investigated the earth erbia, which yielded ytterbium to Marignac, affirms the existence therein of two other new metals, *holmium* and *thulium.* From the copper-nickel of Kragerö (Norway) Dahll has succeeded in isolating what he affirms to be a new metal, which he calls *norwegium.*—*Am. Jour. Sci. and Arts,* xvii, 478; xviii, 141, 400, *et seq.*

Delafontaine affirms that he has succeeded in detecting Marignac's ytterbium in the mineral sipylite from Amherst, Va., and W. G. Brown claims to have observed the spectrum lines characteristic of Delafontaine's phillipium in the same mineral. The existence of a new member of the platinum group from the Ural is also re-affirmed, and given provisionally the name *ouralium.* How many of these alleged discoveries will stand the test of future investigation it would be hazardous to predict. Time alone can bring order out of what appear, at least in the case of several of the above new (?) elements, to be conflicting discoveries.

Mr. S. B. Christy contributed an important paper to the California Academy of Sciences, on the *Genesis of Cinnabar deposits,* to determine the question whether these deposits were formed by deposition from solution or by sublimation. The author shows that cinnabar is soluble in alkaline sulphides at temperatures between 150° and 250°C. and at pressures of from 200 to 500 pounds per square inch. He holds that the preponderance of evidence is in favor of the view that the

deposits of cinnabar as they exist at present, *in situ*, are the result of deposition from solutions in alkaline menstrua, under conditions not unlike those by which he has succeeded in producing the mineral artificially.—*Proc. Acad.*, 1879.

The artificial production of *pyroxene* was accidentally accomplished and noticed by Messrs. Thomas and Gilchrist in the operation of manufacturing the basic bricks for lining the walls of the Bessemer converter which forms an important element of their process for manipulating phosphoretic pig iron. Those bricks are made of an aluminous magnesium limestone, subjected to a very high temperature in a furnace lined with siliceous fire-bricks; where the lower portion of the charge had come in contact with the siliceous lining a decomposition and partial fusion had taken place. Portions of the fused mass were distinctly crystallized in prismatic crystals of the monoclinic system, semi-transparent, and from colorless to green in color. Hardness 5+, and specific gravity 2·934. Analysis showed it to be a bi-silicate and a true pyroxene.

Of other contributions to chemical mineralogy, it will be useful to note the fact that F. D. Adams has determined the very general existence of chlorine in members of the *scapolite* family; C. Doelter has added considerably to our knowledge of the correct composition of *spodumene* and *petalite*, and Rammelsberg to that of the *lithia micas*; and Tisani shows that *wagnerite* is identical with kjerulfine. The following new localities and occurrences of minerals are worthy of notice. Genth has identified with *pyrophyllite*, a mineral found by Reinhold in the coal slates of the North Mahanoy Colliery, in Schuylkill Co., Pa., filling out cavities in the slates, and as the petrifying material of coal plants. (*Proc. Am. Phil. Soc.*, xviii, 279). As the result of Mr. Edison's circular of inquiry, the presence of *platinum* has been determined in numerous localities in Idaho, Dakotah, Washington Terr., Colorado, Arizona, New Mexico and British Columbia. In some of these localities the metal is affirmed to exist in considerable quantities.

Dr. Genth's examination of a new locality of *uranium minerals* at the Flat Rock mine, N. C., has yielded some valuable facts concerning the genesis of these species. (*Am. Chem. Jour.*, i, 87). The rounded masses in which they occur were found to contain, in many cases, a nucleus of uraninite; surrounding this is an orange-colored mineral, gummite, and interpenetrating it and forming a crust over it, a light yellow mineral, identified as uranotil. Dr. Genth affirms that gum-

mite is a mixture of uranium hydrate (40·10 p. c.), uranotil (33.38 p. c.), lead uranate (22·66 p. c.) and barium uranate (4·26 p. c.). He also observes autunite at the same locality, associated with phosphuranylite, a new species, described elsewhere. Dr. E. Goldsmith reports the occurrence of *amber and asphaltum* in the ash marl of the cretaceous, at Vincentown, N. J. The last named is found occasionally in masses of 100 pounds weight. The amber is thought to be related to the kranzite of Bergemann. (*Acad. Nat. Sci. Proc.*, 1879). *Percylite* and *schwartzenbergite* are reported to have been found at a new locality in Bolivia. Extensive deposits of a *mineral wax* have been discovered in Utah. The locality is in the Wasatch Range, on the head waters of the Spanish Fork, east from the south end of Utah Lake. The material, variously described as ozocerite and zietrisikite by Newberry and Wurtz respectively, who differ as to its identity, is found saturating beds of bluish shales of (probably) tertiary age, over a tract of country 50 to 60 miles in one direction by 20 miles in another.—*Eng. and Min'g Jour.*, Dec., 1878—Jan., 1879.

Claasen has identified *cacoxenite* on the martite of Lake Superior. It appears in acicular crystals of brown yellow color, forming radiating tufts. Dr. J. Lawrence Smith has made an elaborate investigation of the *native iron* of Ofivak and other localities in Greenland (*Ann. de Chim. et de Phys.* (*V*), xvi.) hitherto believed to be of meteoric origin, and affirms them to be terrestrial. B. Silliman notices that the rare mineral *jarosite* occurs quite abundantly in the quartz veinstone of the Vulture mine in Arizona.—*Am. Jour. Sci.*, xviii, 73.

Maskelyne describes rock masses from two localities in the Transvaal in South Africa, consisting solely of massive *enstatite*.

For the benefit of those readers of the JOURNAL who may be interested in the subject, an alphabetical list of the new mineral species and varieties that have been described in the journals during the year just passed is herewith appended, together with a brief description of the more important members of the list.

ABRIACHANITE—a doubtful species—described by Heddle, and named provisionally with several other substances, "which may prove to be new Scottish minerals." It is described as an impure, bluish, clay-like mineral.—*Min. Mag.*, 1879, 57. *Am. Jour. Sci.*, xviii, 484.

ANIMIKITE, an antimoniuret of silver, resembling metallic silver, which its discoverer holds to be a new member of the dichrasite family. Found at Thunder Cape, near Silver Islet, where it was taken for

native silver. Described by Dr. Henry Wurtz.—*Eng. and Min'g Jour.*, Feb. 22, 1879.

BERNARDINITE, a new mineral resin from San Bernardino Co., Cal. A light, porous, friable mass of yellowish-white color, that floats on water; dissolves readily in alcohol, ether or potassa, and forms an emulsion with water on boiling. It is probably a mixture of several resins. Described by J. M. Stillman.—*Min'g and Sci. Press*, 1879.

BHRECKITE, a chloritic mineral named provisionally by Heddle as a probable new Scottish mineral.—*Ref.* Abriachanite *ante.*

BRASS (native). Specimens of what appear to be a native brass are reported to have been found on the Yuba river in Sierra Co., Cal. They are described as being in the form of small, flattened, concretionary masses, destitute of crystalline structure, yellowish to red-brown in color, with a faint yellowish streak. Comp. 85·02 p. c. copper, 11·02 p. c. zinc. Described by J. M. Stillman.—*Ref.* Bernardinite *ante.*

CLINOCROCITE, a hydrous sulphate found at the Bauersberg, near Bischofsheim. Described by S. Singer.—*Ref.* Abriachanite *ante.*

CLINOPHAEITE, a hydrous sulphate. Same locality. Singer.—*Ref.* Abriachanite *ante.*

EGGONITE, a new silicate (containing cadmium?) occurring in minute crystals of a brown color on calamine from Altenberg, near Aachen. Described by Schrauf.—*Zeitsch. Kryst.* iii, 352.

FAIRFIELDITE, a hydrous phosphate of manganese and calcium with small quantities of iron and sodium; found associated with *reddingite* and *fillowite*, at the new mineral locality at Branchville, Fairfield Co., Conn. Its color is yellowish white to colorless and transparent, with adamantine lustre on the best cleavage planes. Described by Brush and E. S. Dana.—*Am. Jour. Sci. and Arts*, xvii, 259, *et seq.*

FILLOWITE, a hydrous phosphate of manganese, sodium and iron. Found at the same locality as the mineral just described. Occurs in crystalline masses, and rarely in distinct crystals of a wax yellow to brown color, at times almost colorless. Crystallization monoclinic. Described by Brush and E. S. Dana.—*Ibid.*

GEDONITE, a fossil resin occurring with the amber of the Baltic, and distinguished from the latter by its greater friability, lower point of fusion and more ready solubility. Described by Helm.—*Eng. and Min'g Jour.*, March 13, 1879.

HANNAYITE, a hydrous phosphate of magnesia and ammonia found

in the guano of the Skipton caves in Victoria, N. S. W. Crystallization triclinic, with perfect basal cleavage. Described by Vom Rath.—*Vide, Newberyite*

HERRENGRUNDITE, a basic cupreous sulphate, found associated with gypsum, malachite and calcite from Herrengrund, Hungary. Crystallization monoclinic (?) with perfect basal cleavage; color dark merald green. Described by Bretzina.—*Zeitsch. Kryst.*, iii, 359. *Am. Jour.* xviii, 484.

HOFMANNITE occurs in colorless, tasteless, tabular crystals in lignite, with a composition $C^{20}H^{36}O$. Described by Bechi (Pisa).—*Ibid.*

HOUGHTONITE, a new species (?) of mica from the hornblendic gneiss of Roneval, Scotland. It has a jet black color, transmitting brown light in thin plates. Described by Heddle.—*Ibid.*

HUNTILITE, a new arsenide of silver found at Silver Islet, Lake Superior. Two varieties are found, the most abundant being amorphous or cryptocrystalline and of a slate gray to black color, while a crystalline variety is of a light slate color. Both varieties are somewhat malleable under the hammer, and take a burnish when rubbed with a knife blade. They give a lustrous bronze streak on ground glass. The discoverer holds the affiliations of huntilite to be with the dichrasites and domeykites, regarding it properly as a silver domeykite, but constituting the first member of a new series of mineral homologues. Described by Wurtz.—*Eng. and Min'g Jour.*, Jan. 25th, 1879.

LEUCOMANGANITE, a snow-white, foliated and radiated mineral, colorless in thin plates, but fusing readily before the blowpipe with brownish discoloration. Chemical composition not accurately known, but containing manganese and iron protoxides, alkalies and water. Described by Sandberger.—*N. Jahrbuch f. Min* , 1879, 370.

LOUISITE, a hydrous silicate of lime and potassa with small quantities of iron (protoxide), found at Blomidon, N. S. It is a leek-green, translucent, vitreous mineral, brittle with splintery fracture, and gelatinizes with hydrochloric acid. Analyzed by H. Louis and named by D. Honeyman.—*Am. Jour. Sci.*, xviii, 484.

MALLARDITE, a new hydrous sulphate of manganese found at Lucky Boy silver mine, Utah. Occurs in small fibrous, monoclinic crystals, at first colorless and transparent, but which soon effloresce on exposure to the air, losing two equivalents of water. Described by A. Carnot.—*Jour. Chem. Soc.*

NEWBERYITE, found with hannayite in the guano of the Skipton

Caves, Victoria, N. S. W. A hydrous phosphate of magnesia; crystallization orthorhombic. Described by Vom Rath.—*Bull. Soc. Min. France*, 1879; *Am. Jour. Sci.*, xviii, 487.

PLAGIOCITRITE, a new hydrous sulphate from the Bauersberg, near Bischofsheim. Described by Singer.—*Am. Jour. Sci*, xviii, 484.

PHOSPHURANYLITE, a new hydrous phosphate of uranium, found at the Flat Rock mine, in Mitchell Co., N. C., occurring in the mica-bearing portion of a large granite vein with other uranium minerals. Found as a thin coating on quartz, feldspar and mica. The mineral has a deep lemon yellow color, and under the microscope shows minute rectangular scales of a pearly lustre. Described by Genth.—*Am. Chem. Jour.*, i, 87.

RANDITE, a hydrous carbonate of calcium and uranium found as a lemon-yellow incrustation on granite near Philadelphia. The mineral is related to liebigite. Described by Koenig.—*Acad. Nat. Sci. Proc*, 1878, 408.

REINITE, a tungstate of iron, isomorphous with scheelite and scheelitine, brought from Japan (Kimbosan) by Dr. Rein. Found associated with quartz, forming large, well-developed crystals of brownish-black color, closely resembling those of the above-named minerals. Described by Dr. Luedecke.—*N. Jahrbuch f. Min.*, 1879, 568.

TITANOMORPHITE, a titanate of lime, held to be the product of the alteration of titanium minerals (ilmenite and rutile). It is found in hornblende slate near Reichenbach, in Silesia, surrounding crystals of rutile. It has a yellowish-white color, and a granular or fibrous texture. Described by von Lasaulx.—*N. Jahrbuch f. Min.*, 1879, 568.

URUSITE, a hydrous sulphate of ferric oxide and soda, found in the Caucasus associated with gelbeisenerz and copperas. Color from lemon-yellow to orange, and is found in bulbous masses (or pulverulent), which, when crushed, show the glitter of the small crystals of which the mass is made up. Described by Frenzel.—*N. Jahrbuch f. Min.*, 1879, 89.

URVÖLGYITE (see Herrengrundite, *ante*). Szabó, who describes this species, differs from Brezina in making the lime obtained in the analysis an essential constituent of the mineral, while the latter ascribes it to the presence of gypsum.—*Tsch. Min. Mittheill*, ii, 311.

WATTEVILLITE, a hydrous sulphate found at the Bauersberg, near Bischofsheim. Described by Singer.—*Am. Jour. Sci.*, xviii, 484.

XANTHOLITE, a mineral having nearly the composition of staurolite,

but thought to have a monoclinic crystallization. Described and named provisionally by Heddle, as a probable "new Scottish mineral." —*Min. Mag.*, 1879, 57.

Of new varieties, the following are of special interest:

A *titaniferous crysolite*, having a red color, and containing 6·10 p. c. of titanic acid, has been found at Zermatt, Switzerland. Described by Damour.—*Bull. Soc. Min. France*, ii, 15.

A *gelatinous silicate*, found near Lausanne, Switzerland, has the consistency of paste when taken out, but gradually solidifies. It has the composition of chabasite. Renevier, who described it, calls it "a mineral in an embryotic condition."—*Bull. Soc. Vaud*, xvi, 21; *Am. Jour. Sci.*, xviii, 72.

A *mangano-calcite*, carrying 2·04 p. c. of barium carbonate, occurs in a crystalline limestone at Laangban. Described by Sjogren.

A *barytic feldspar*, carrying over 7 p. c. of baryta, is described by Descloiseaux. Cleavage angles were identical with those of labradorite, while its optical properties allied it with albite and oligoclase. Locality was unknown, but the mineral resembled the albite from Steiermark.

Luckite, a new variety of ferrous sulphate. It is found in small distorted crystals, probably monoclinic, having a slight tinge of blue. The mineral carries a small percentage of manganese; composition SO^4 (Fe Mn) + $7H^2O$. Ratio of Mn to Fe as 1 : 10. It is regarded as being intermediate between melanterite and mallardite, but differs from both by not altering on exposure to air. It occurs at Lucky Boy silver mine, Utah, and is described by Carnot.—*Jour. Chem. Soc.*

In crystallographic mineralogy, it may be interesting to note that Streng, from a study of the optical characters and an accurate measurement of the angles of the crystals of *pyrostilpnite* (fireblende), pronounces this mineral to belong to the orthorhombic and not to the monoclinic system; and that Baumhauer, from an investigation of the etching figures produced on crystals of *boracite* by acids, is led to the conclusion of Mallard, that the species belongs to the orthorhombic and not to the isometric system.

Magnetic Influence on Atmospheric Polarization.—Henri Becquerel infers, from recent observations upon skylight polarization, the existence of a variable difference between the solar plane and the plane of polarization, and the manifestation of a magnetic influence by the earth upon the atmosphere.—*Comptes Rendus.* C.

SILK CULTURE.

By Sam'l Chamberlaine, M.D.

The United States Agricultural Report from the Census of 1870 contains, at page 241, the following passage respecting silk culture: "In consequence of the diseases of the silkworm, the imports of raw silks into Great Britain have fallen off 40 per cent., and prices have risen 100 per cent. Imports of silk from China between 1857 and 1864 fell from nine millions of pounds to three millions of pounds. To remedy this evil, the silk manufacturers of England have formed a company, 'The Silk Supply Association,' the object of which it to stimulate silk production by cottage culture."

The notice thus given of a deficiency in this important article of luxury, the producing and manufacturing of which has been so largely productive of wealth to three great countries—China, Japan and France—drew renewed attention to the subject in the United States, and induced in several parts of the country a desire to repeat the efforts made in 1830 to 1840, but upon a better and wiser method than was pursued at that period. It was remembered by many that the originator of the silk excitement in that decade (M. D'Homergue, a native of the silk provinces of France and brought up amongst silk-growers) had declared his belief "that the United States are destined to become a great silk-growing and silk-manufacturing country; that the fulfillment of this high destiny may be retarded, but nothing can prevent its taking place at some future time" (page 63 of letters to Mr. Peter S. Duponceau).

The development of the unhappy excitement of that period into a wild and wicked speculation in mulberry trees proved that this industry could not be made sufficiently profitable to any individual to induce the prosecution of it alone; that it requires combination, both of individuals to cultivate the silkworms on a sufficiently large scale, and of capital to regulate the purchase and sale of the silk products. The English idea of *cottage culture*, stimulated and regulated by an organized company, is being pursued in their Australian colonies. We saw something of their success during the Centennial Exhibition of 1876. It remains for us Americans to adopt and apply to our own country

the wise suggestion and example they have given us. To further this hoped-for application the following statistics are presented through the JOURNAL OF THE FRANKLIN INSTITUTE. And first in regard to the whole silk supply of all the silk-producing countries. It appears that there is at all times a relative deficiency, *i. e.*, that the supply is subject to very great and very sudden fluctuations as to quantity, and that while on the whole there is a general increase of production, this does not keep pace with the increase of demand. The adulterations and the intermixture of other textile fibres of less strength and less durability fill the demand for the time. It would be much better filled by the silk alone, were the production itself increased. It is therefore true that in the world's markets there is always ready sale for raw silk. The statistics presently to be introduced will show that in our own markets there is a steadily and rapidly increasing demand for it. The irregularity of the production is very forcibly shown by the following table of prices at London, taken from Secretary Wyckoff's "Silk Goods in America" (published in 1879):

	Chinese Tsaltee, No. III.			Japan Maibash.			Italian best Organzine.		
		s.	*d.*		*s.*	*d.*		*s.*	*d.*
	1860	23	6		27	6		43	6
Av. 24s. 1d. $6.00	1861	19	6	Av. 28s. 1d. $7.00	24	0	Av. 36s. 9d. $9.18	40	0
	1862	23	0		28	0		31	0
	1863	22	0		24	6		35	0
	1864	25	6		28	6		32	0
	1865	31	0		35	6		46	0
Av. 29s. 1d. $7.25	1866	26	0	Av. 33s. 3d. $8.30	30	0	Av. 46s. 4d. $11.60	37	0
	1867	32	0		36	0		50	0
	1868	29	0		33	0		60	0
	1869	30	0		35	0		45	0
	1870	29	0		32	6		40	0
Av. 22s. 4d. $5.60	1871	29	0	Av. 24s. 0d, $6.00	29	0	Av. 38s. 4d. $9.60	44	0
	1872	28	6		30	0		46	0
	1873	21	6		24	6		38	0
	1874	18	0		21	6		35	0
	1875	17	0		15	0		29	0
Av. 24s. 6d. abt. $6.00	1876	28	6	Av. 25s. 9d. abt. $6.40	33	6	Av. 38s. 3d. abt. $9.50	46	6
	1877	20	6		18	0		30	0

It is of interest to know what may be the product of the whole silk-producing countries of the world, and attempts have been made to arrive at some probable estimate, notwithstanding the difficulty of collecting statistics from so many countries and from such variety of

returns. Two tables of approximate results we present below, the one taken from the *American Exchange and Review* for October, 1870, and the other from Dr. Brockett's *Silk Industry*, published, in 1876, under the auspices of the Silk Association of America, and for the Centennial Exhibition. Both tables give only the value in dollars, but, as it is desirable to form an idea of the production in pounds, I have used a table of Dr. Brockett's work (page 203) to obtain an average price per pound, and from it to deduce the amount of silk supposed to have been furnished by each silk region:

Country.	Av. value.	Total value.	Estimated in lbs.	Total value.	Estimated in lbs.
		1870.		1876.	
Chinese Empire...	$4	$81,600,000	20,400,000	$92,928,000	23,232,000
Italy and Pontiff. States.....	8	40,500,000	5,065,000	59,250,000	7,406,000
India.....	3	24,000,000	8,000,000	35,200,000	11,733,000
France.....	8	25,000,000	3,125,000	31,246,800	3,903,000
Japan and Corea..	4	18,100,000	4,525,000	19,800,000	4,950,000
Syria and Asia Minor.....	6	7,000,000	1,166,000	8,500,000	1,416,000
Turkey in Europe	6	7,000,000	1,166,000	7,920,000	1,320,000
Persia, Turkistan, etc.....	6	6,400,000	1,066,000	6,250,000	1,041,000
Austria and Hungary.....	8	1,280,000	156,000	3,087,000	386,000
Spain & Portugal	7	3,200,000	457,000	1,884,000	269,000
Greece.....	6	840,000	140,000	1,087,000	181,000
Morocco.....	6	300,000	50,000	300,000	50,000
America (probably Mexico, Brazil & California)	6	80,000	13,000	100,000	16,000
		$215,300,000	45,333,000	$267,553,400	55,903,000

This table shows the sources of the world's supply of raw silk, and the importance, in money value, of the industry to those countries. It shows a much wider distribution of the industry than is commonly supposed to exist. It shows, also, the almost total neglect of this valuable product on the Continent of America; while the exhibit of a paltry 16,000 pounds proves that somewhere it is being made, and therefore that a much more extensive production is possible. It shows that the long-settled and densely populated countries are those that produce the greatest quantity, and we may infer that a certain degree of concentration and stability of population is necessary to its successful pursuit. The increase in the six years interval between these tables has

been about 25 per cent., that is, about 4 per cent. per annum during a period of unusual and wide-spread inactivity in business, which has lessened the consumption of silk goods greatly more than of any other material of wear, silk being necessarily classed amongst the luxuries, and not among the necessaries of life. This rate of supply must fall far short of the demand when the increased activity of all trade shall increase the consumption of silk goods also in a like ratio. Hence the importance of effort on the part of Americans to add this product to our present industries, since there is sure to be a large and increasing demand for it within a few years. But a very important part of the usual supply is known to have been steadily decreasing during the past fifteen or more years. Italy and France together have furnished about one-fifth of the whole. In these countries the diseases amongst the silkworms have prevailed, and have shortened their crops continually, year by year, as the following table, from Secretary Wyckoff's work (page 12), will show in regard to Italy, and no doubt a like return from the French districts would show a similar decrease.

Annual Silk Product of Italy.

Before the Pebrine disease, 3,710,000 kilos.

in 1863	2,308,000	"	loss, 38 per cent.
1864	1,731,000	"	" 53 "
1865	1,762,000	"	" 52 "
1866	1,800,000	"	" 51 "
1867	2,000,000	"	" 48 "
1868	1,900,000	"	" 49 "
1869	2,150,000	"	" 42 "
1870	3,180,000	"	" 14 "
1871	3,473,000	"	" 6 "
1872	3,125,000	"	" 16 "
1873	2,960,000	"	" 20 "
1874	3,430,000	"	" 7 "
1875	3,073,000	"	" 17 "
1876	1,010,000	"	" 72 "
1877	1,853,400	"	" 50 "
1878	2,650,000	"	" 28 "

The average annual product for these sixteen years was 2,400,338 kilos., which is 1,309,662 kilos. less than the annual product before the disease assailed them. This amount, estimated in pounds avoirdupois ($2\frac{1}{8}$ to the kilo.), is 2,873,256 lbs. This is, therefore, the deficiency in Italy alone, and this large amount must be made up either by increasing the production in the Eastern countries, or by finding in America a new and wide field for extending it. The deficiency, in

fact, is much greater than this, for it must be doubled for France, where the disease has prevailed with even greater virulence; and more than doubled, if we include, also, the countries upon the Mediterranean to which it has spread in perhaps a less degree. The existence of this disease has induced a trade of no small amount between France and Italy, as purchasers, and Japan (chiefly) as seller of silkworms' eggs. The magnitude of this trade is indicated by the statement in the *Public Ledger* of the 23d Dec., 1879, that six freight cars filled with cards of silkworms' eggs had arrived from San Francisco at New York, on the way from Yokahama, Japan, to Havre in France. The value is stated in the article at $850,000, but this is probably an under-statement, or the cargo is but a part of that which the same article promises will arrive in January. In the years 1874, 1875, 1876, 1877 similar cargoes passed over the Pacific Railroad, and were estimated in the papers of each of those years at $6,000,000, the numbers of the cards of eggs and their value ($5.00 per card) being stated.

There is no reason why Americans should permit this trade to pass through our borders without making an effort to participate in its profits. In truth, there have been some small invoices of eggs sent from Kansas, from Alabama and North Carolina. The expense of raising the eggs is very small, and the profits quite large in proportion, while the trade may be expected to last for a good many years to come, since the French and Italians have found advantage in a constant renewal of their stock.

This decrease of production in Europe is further shown in the following extract from the *Country Gentleman* of October, 1879, which brings the statement down to the present year:

	1878.	1879.	
Silk crop of Europe.....	7,326,000 lbs.	2,510,200 lbs.	= ⅓.
" Asia.....	11,541,200 "	12,221,000 "	= slight advance.
Total.....	18,867,200 "	14,731,200 "	= ¼ less.

Resnlt.—Crop of 1879 less than of 1878 by 4,000,000 lbs.
and less than the average of 5 years by 3,960,000 "

While there is shown to be a lessened supply of raw silk, we have abundant evidence that the consumption of it in the United States is continually increasing, and that steadily so that something like a rule seems to be exhibited by the statistics of its importation. The rate of increase appears to be, that the average annual importation doubles every five years. The manufactures by American

silk mills have so grown in popularity that the domestic goods have succeeded in gaining half the United States market from the foreign manufacturers, and the number of firms engaged in this work has increased at the rate of 50 per cent. in four years, as the following, from Dr. Brockett's work, shows:

Firms reporting to the Silk Association.

May, 1873,	147	firms,	employing	11,713	operatives.
" 1874,	156	"	"	10,651	"
" 1875,	180	"	"	14,479	"
" 1876,	213	"	"	18,017	"

These firms have produced silk goods of the value of $25,000,000 in 1872 to $27,000,000 in 1876, and have gained upon the foreign importations at the following yearly rates:

Calendar Year.	Home Production.		Importation.		United States Consumption.	Proportion per cent.
1872	$25,073,201	+	$32,677,749	=	$57,750,950	43·4
1873	19,894,874	+	24,379,322	=	44,274,196	44·6
1874	20,082,482	+	23,292,551	=	43,375,033	46·3
1875	27,158,071	+	23,168,118	=	50,326,189	53·9
1876	26,593,163	+	21,192,386	=	47,785,549	56·4
1877		+	19,922,741	=		
1878		+	20,042,730	=		

When the values of home production for the years 1877 and 1878 are ascertained it will be found that the proportion to the amount imported has not lessened, although the total of consumption will probably be less, in accordance with the continued depression of general business in those years. The table bears out the assertion that our silk mills are gaining possession of our home market, and that by not slow steps.

Previous to 1850 the number of firms engaged in importing and manufacturing raw silk were so few and the amount so insignificant that no separate account was taken at Washington of the importations, nor was the quantity of raw silk noted until the end of the fiscal year (June 30th) 1864. The business of manufacturing rises into importance only after 1850, when the success attained by Mr. John Ryle, at Paterson, N. J., had attracted others to engage in the business. It should not be forgotten by those who think the "Morus Multicaulis Mania" was all loss to the country, that out of it arose the thirty (now perhaps fifty) firms at Paterson, and the city itself, with (probably)

60,000 inhabitants. John Ryle and Wm. H. Horstmann were brought over from the English silk mills in which they were employed, by reports of the great amount of silk that was being produced in the United States. They both established the large firms of which they were the heads, the one in Paterson, the other in Philadelphia. These were the outcome of Samuel Whitmarsh's failure. They were both employees of the great "King of Multicaulis," as Whitmarsh was called.

The growth of the silk business is best shown by reducing the extensive tables (from Washington) found in Dr. Brockett's work to averages for the half decades:

Fiscal years (inclusive).	Average No. lbs.	Total value for 5 years.	Annual cost.
1851 to 1855.....	not stated	$3,467,384	av. $693,477
1856 to 1860.....	not stated	6,347,425	av. 1,269,485
1861 to 1865.....	av. 348,978	6,503,365	av. 1,300,673
1866 to 1870.....	av. 575,524	12,555,337	av. 2,511,067
1871 to 1875.....	av. 1,044,005	27,789,815	av. 5,557,963

During the five years, 1860 to 1865, the civil war lessened the rate of increase, but did not break up the business, nor even prevent a slight increase of the importation. In the second five the amount was nearly doubled, in the third stationary (on account of the war), in the fourth almost double again, and in the fifth more than doubled. We might fairly expect to find the annual amount stationary again during the period from 1875 to 1880, but the promise thus far is of a large increase, and perhaps with the sudden increase in all other businss this also may show a continuance of its rate of doubling, when the returns for 1880 are ascertained. For three years of the period we have the following:

Fiscal year.	No. lbs.	Annual cost.
1876, . .	1,144,860	$11,874,570
1877, . .	1,007,504	8,456,341
1878, . .	1,590,633	6,807,725

The last year showing a very large increase in the quantity imported, while the year 1876 was an exceptional year as to price, which rose to more than double its usual value, and to an average for the year of $10.37 per pound as against the usual average of about $5.00 (plus importer's charges).

It may be gathered from these statistics that there is in the United

States an established, settled business in silk manufacturing; that it employs at least 200 firms and some 20,000 operatives, who consume more than 1,000,000 pounds of raw silk, for which more than $5,000,000 have been annually sent out of the United States, and that the annual export of gold for this raw material will soon reach $10,000,000, and probably in the near future $20,000,000. All this may be readily produced in our own country, and a large part of it in the State of Pennsylvania, which in 1844 produced some of the best silk then used by Mr. John Ryle's "Murray Mills," in Paterson. It needs but a discreet following of the example set us by the English Society to encourage in every practicable way the raising and reeling of silk as "a cottage culture" and a country production. An association, whose headquarters should be in Philadelphia, would be able to institute, and then foster and encourage, the industry in all parts of the country. It would distribute trees, eggs and apparatus to every favorable locality; it would gather up the cocoons for reeling and the reeled silk itself from all parts of the country; it would be able to sort and sell at wholesale to the consumers the quantities and qualities suitable for their business; it would so regulate the entire business as to prevent the recurrence of mad speculation by which alone the prospects of establishing the rich industry were dashed in 1840; it would enable us to see fulfilled the first part of M. D'Homergue's prediction, as we already see by the tables that the second part has been fulfilled. The United States have become a rich silk manufacturing country; it remains for us to make her a rich silk growing country.

December 26th, 1879.

A STATEMENT CONCERNING THE RELATION OF THE LAWFUL STANDARDS OF MEASURE OF THE UNITED STATES TO THOSE OF GREAT BRITAIN AND FRANCE.

By J. E. HILGARD,
Assistant United States Coast and Geodetic Survey.

UNITED STATES COAST AND GEODETIC SURVEY OFFICE,
Washington, D. C., July 8, 1879.

SIR: I submit the following statement in relation to the American, British and French standards of measure, conceived in a brief and categorical form, in order to explain statements heretofore made from this office, as well as to give trustworthy data for books of instruction.

It is desirable, for the sake of perspicuity, that the following principal statements should be made:

1st. There is no difference between the standards of weight of Great Britain and those of the United States.

2d. The standards of volume in the United States are the same as those lawful in Great Britain prior to 1826.

3d. There is no difference between the standards of length of Great Britain and those of the United States.

4th. The relation of the American and British standards to the French metric standards is not determined with extreme precision, but the legal enactments [see Annex I] will suffice for all purposes, except those of great scientific accuracy.

Measure of Weight.

In regard to the standards of measure in customary use in the United States, it should be observed that they have been inherited by our ancestors from England together with the common law. No enactment by Congress has ever been made declaring particular measures in the keeping of the government as standards, except the standard troy pound of the Mint of the United States at Philadelphia, which is an exact copy of the Imperial troy pound of Great Britain procured in 1827.

Elaborate comparisons, made at various times from the year 1855 up to the present date, of this troy pound, containing 5760 grains, and of the commercial or avoirdupois pound, containing 7000 grains, derived from the former, with copies of similar weights derived from the standard pound of Great Britain, have shown that there is not so much as one-thousandth of a grain outstanding between the money standards of the two countries.

Measure of Capacity.

Of the measures of capacity, which are not measures of great precision, it is only necessary to say that the old British wine gallon of 231 cubic inches, and the old Winchester bushel, containing 2150·5 cubic inches, are the recognized standards in the United States, as they were the lawful standards before the separation of the colonies from Great Britain, no subsequent enactment having been made.

Measure of Length.

The measure of length, which is the yard of 36 inches, is legally in the same condition as the measures of capacity. The standard yard of

Great Britain was lawful in the colonies before 1776. By the Constitution of the United States the Congress is charged with fixing the standard of weights and measures (Art. I, Sec. 8); but no such enactment has ever been made by Congress, and therefore that yard which was standard in England previous to 1776 remains the standard yard of the United States to this day—the same being also true of the commercial or "avoirdupois" pound, and of the gallon and bushel, as above stated.

It must not be supposed that this is a matter which, in view of the great questions of public policy engrossing the attention of Congress in early years, had remained without due consideration. The journals of both houses of Congress show that committees were early appointed for the consideration of the subject. A Senate committee reported on March 1, 1791, that "it would not be eligible at present to introduce any alteration in the measures and weights which are now used in the United States." Other reports were made from time to time, and in January, 1820, a committee of the House of Representatives presented their conclusions, which were: "That little should be done; that standards conformed to those in most common use among us should be accurately made and carefully preserved at the seat of government; that correct models should be placed in different districts of the country; and that the proportions and relations between these should be ascertained."

Again, on March 11, 1822, a committee report was submitted to the same body, making recommendations for rendering "uniform and stable the measures and weights which we at present possess."

Thus, after full consideration for thirty years, it was agreed that the matter was in a satisfactory shape, in virtue of our inheritance and traditions, and that no legislation was advisable.

Finally, in 1836, an act was passed directing the Secretary of the Treasury to cause copies of the weights and measures adopted by the Department as standards, for the use of custom-houses, to be supplied to each State, "to the end that a uniform standard of weights and measures may be established throughout the United States." The standards so "adopted" were those of Great Britain, as before described.

The actual standard of length used was a bronze scale of 82 inches, subdivided on silver to tenths of inches, which had been prepared for the Coast Survey of the United States by Troughton, of London. The 36 inches comprised between the 27th and 63d inches, found equal to

the average of the whole scale, were taken as the standard yard, and the temperature at which this was considered to be a standard, that is to say, equal to the British Standard Yard, was presumed to be 62° Fahr. It had, however, never been directly compared with that standard, but was simply copied from Troughton's own scale without subsequent verification.

In England, the old standard yard, known as Bird's Standard of 1760, had in the meantime been found to be inadequate in definition for the increasing requirements of science, and a new set of standards of length, weight and capacity was constructed between 1816 and 1826 of such finished workmanship and precise definition as was required by the science of the time, and every effort was made to reproduce, with the greatest possible exactness, the old standard pound and yard.

Not long after this important work had been accomplished, the standards so constructed were destroyed by the burning of the Parliament buildings in 1834. They have since been reproduced by reference to all of the former accredited standards with which they had been originally compared, and are now known as the "Imperial Standards." Some fifty copies of these standards were constructed and intercompared, and certain of these have been sent to the United States. The avoirdupois pound of 7000 grains is found to agree within one-thousandth of a grain with the avoirdupois pound of the United States, derived from the Mint-pound heretofore mentioned—an agreement which leaves no question outstanding as to the identity of the units of weight of Great Britain and the United States.

The comparison of the Troughton scale heretofore mentioned with the Bronze Standard Yard, No. 41, received from Great Britain in 1856, shows the former to be longer by nearly one-thousanth of an inch in the yard, or, more precisely, 0·00085 inch. By very recent comparisons, however, made by myself at the British Standards Office between the standard Imperial yard and Bronze, No. 11, the latter was found to be 0·000088 inch shorter than the former, which may be stated in the form that it is of standard length at a temperature of 62·25° Fahr. Hence we infer that at 62° the Troughton scale is too long by 0·00076 inch, or that it is standard at 59·8 Fahr., instead of 62°, as formerly assumed; and this correction will apply to all measures that have been derived from it. This change, although sensible in operations of extreme scientific precision, is really of no consequence in ordinary practice, as it amounts only to the 1:45,000th part of the

whole length—a degree of accuracy which is seldom required. The correction does not exceed the thickness of one of the lines that define the yards supplied to the States.

Extreme accuracy in this matter is beset with great difficulties, for in addition that of ascertaining for each particular bar the rate of dilatation by temperature, there is an uncertainty in regard to permanence in the length of the bars themselves. Of the two standard yards presented to the United States, one is of bronze (No. 11), and the other of Low Moor wrought iron (No. 57). These are found to have changed their relative length by 0·00025 inch in twenty-five years; the bronze bar being now relatively shorter by that amount. This subject is undergoing further investigation.

Relation of Yard to Metre.

Statements in regard to this relation have varied excessively, comparison between the two standards being subject to two great difficulties: first, their different nature and definition, and second, their incommensurability in length. The metre is a platinum bar, cut to length (an *end-measure*), and standard at the temperature of melting ice (32° Fahr.) The length of the yard is defined by lines drawn on a bronze bar, standard at a temperature of 62° Fahr. The difficulty of making accurate comparisons of lengths so differently defined is at once apparent; moreover, as their relative length is such that the metre is something longer than 39·37 inches, it is necessary first to derive the latter length from the yard of 36 inches by minute subdivision into a scale of equal parts, and the addition of the odd amount, a process which involves so many successive operations that the probable error of the result is largely increased by an accumulation of uncertainties.

From these circumstances have arisen the differences in statements of the length of a metre expressed in inches. One of the earliest trustworthy comparisons was that made by Kater, giving the value, generally quoted, of 39·37079 inches. This comparison was made with one of the earlier British standards. A more recent determination is that made by Clarke, at the office of the British Ordnance Survey, between a number of the new British standards and several well-accredited copies of the metre, which give, very accordantly, a value of 39·37043 inches. It appears that in the latter observations the coefficients of expansion of the bars used were more accurately ascertained than in the former, and as between these two values the latter probably deserves the preference.

It must be observed, that since both yard and metre are material things, no legislative declaration in regard to their relative value can have any force other than to define what shall be considered lawful equivalents. This circumstance being recognized, when the metric standards were made optional in the United States, Congress, instead of stating the equivalents with excessive minuteness, as was done in Great Britain, merely defined the relation which shall be held lawful, to a degree of precision sufficient for practical purposes; thus we find in the table annexed that the lawful equivalent of a metre is 39·37 inches.

In the United States, Professor Hassler, first Superintendent of the Coast Survey, made very careful comparisons between one of the original metres and the Troughton 82-inch scale. The records of his experiments are not now extant, having been destroyed by fire in 1843, but he has published his results, viz.: One metre = 39·38092 inches of the bronze yard, reduced to 32° Fahr. He made use of a coefficient of expansion resulting from some experiments made by himself upon a brass wire, which value is much too large; but we cannot now correct his reduction, because we do not know the actual temperatures of comparison. Using Mr. Hassler's rate of expansion, viz., 0·0003783 inch in one yard, for 1° Fahr., and reducing his result to the standard temperature of the yard (62° Fahr.), his successor, Professor Bache, found the value of the metre to be 39·36851 inches of the Troughton scale, then the only accredited standard in our possession. When, however, we apply to the latter the correction of 0·00076 inch in a yard, found as above stated, and ascribe to it the rate of expansion of other bronze alloys—for instance, that found by Airy, from Sheepshank's observations, for the bronze of which the new Imperial standards are made, viz., ·000342 inch per yard—we find one metre = 39·37054 inches, as follows:

Hassler's value of metre, reduced to 62° . .	39·36851
Correction for difference in rate of expansion, . .	+ 0·00119
Correction for excess of Troughton scale in one metre, .	+ 0·00084
Hassler's comparisons, corrected reduction, .	39·37054

a value which differs very little from that obtained by Clarke, although it cannot be claimed to possess the same degree of trustworthiness. In fact, if we substitute in the above reduction the rate of expansion for the bronze of the British standards recently determined by Fizeau, viz., 0·000351 inch per yard, we shall get 39·37023.

The value 39·3685 inches, derived, as above mentioned, from Mr. Hassler's comparisons, was used in the Coast Survey for stating the equivalents in yards of distances known in metres, and it has been so employed, as stated in the respective places, in various lists of geographical positions and tables for projections in the Coast Survey Reports, from 1851 to 1868. Since that time it has been deemed advisable to employ the value obtained by Clarke, viz., 39·3704 inches. The conversion is readily made with very sufficient accuracy, by increasing the distances in yards by their 1 : 20,000th part. A table of equivalents is given below (Annex II).

It is not practicable to attain greater precision in comparison until after the completion of the new international metres now in course of construction at the International Bureau of Weights and Measures in Paris. When the construction of these shall have been perfected, and when they shall have been thoroughly intercompared, it will be useful once more to attempt to arrive at a closer comparison of the yard and metre than we now possess.

In order to make such a comparison with the least number of successive operations, I have devised the following scheme: Divide a yard into four parts by successive bisections; dividing again the sum of three of these parts into eight equal parts by successive bisections, one of these eighths added to the yard will give the length of the metre with a degree of precision readily within the reach of the comparator; that is to say, the length will be 39·375 inches. Two bars correspondingly divided have been prepared for this purpose, and intercomparison is in progress.

Very respectfully, J. E. HILGARD,
Assistant Coast and Geodetic Survey
in charge of Verification of Standards.

To CARLILE P. PATTERSON, *Superintendent.*

ANNEX I.

An act to authorize the use of the metric system of weights and measures.

Be it enacted by the Senate and House of Representatives of the United States in Congress assembled, That from and after the passage of this act it shall be lawful throughout the United States of America to employ the weights and measures of the metric system, and no contract or dealing, or pleading in any court, shall be deemed invalid or liable to objection because the weights or measures expressed or referred to therein are weights or measures of the metric system.

SEC. 2. *And be it further enacted*, That the tables in the schedule heretofore annexed shall be recognized in the construction of contracts, and in all legal proceedings, as establishing, in terms of the weights

and measures now in usei n the United States, the equivalents of the weights and measures expressed therein in terms of the metric system; and said tables may be lawfully used for computing, determining and expressing in customary weights and measures the weights and measures of the metric system.

Measures of Length.

Metric denominations and values.		Equivalents in denominations in use.	
Myriametre	10,000 metres.	6·2137	miles.
Kilometre	1,000 metres.	0·62137	mile, or 3280 feet 10 inches.
Hectometre	100 metres.	328	feet 1 inch.
Dekametre	10 metres.	393·7	inches.
Metre	1 metre.	39·37	inches.
Decimetre	1-10 of a metre.	3·937	inches.
Centimetre	1-100 of a metre.	0·3937	inch.
Millimetre	1-1000 of a metre.	0·0394	inch.

Measures of Surface.

Metric denominations and values.		Equivalents in denominations in use.	
Hectare	10,000 square metres.	2·471	acres.
Are	100 square metres.	119·6	square yards.
Centare	1 square metre.	1550	square inches.

Measures of Capacity.

Metric denominations and values.			Equivalents in denominations in use.			
Names.	No. of litres.	Cubic measure.	Dry measure.		Liquid or wine measure.	
Kilolitre or stere	1000	1 cubic metre	1308	cubic yards	264·17	gallons.
Hectolitre	100	1-10 of a cubic metre	2	bush. and 3·35 pecks	26·417	gallons.
Dekalitre	10	10 cubic decimetres	9·08	quarts	2·6417	gallons.
Litre	1	1 cubic decimetre	0·908	quart	1·0567	quarts.
Decilitre	1-10	1-10 of a cubic decimetre	6·1022	cubic inches	0·845	gill.
Centilitre	1-100	10 cubic centimetres	0·6102	cubic inch	0·338	fluid ounce.
Millilitre	1-1000	1 cubic centimetre	0·061	cubic inch	0·27	fluid dram.

Weights.

Metric denominations and values.			Equivalents in denominations in use.	
Names.	No. of grams.	Weight of what quantity of water at maximum density.	Avoirdupois weight.	
Millier or tonneau	1,000,000	1 cubic metre	2204·6	pounds.
Quintal	100,000	1 hectolitre	220·46	pounds.
Myriagram	10,000	10 litres	22·046	pounds.
Kilogram or kilo	1,000	1 litre	2·2046	pounds.
Hectogram	100	1 decilitre	3·5274	ounces.
Dekagram	10	10 cubic centimetres	0·3527	ounce.
Gram	1	1 cubic centimetre	15·432	grains.
Decigram	1-10	1-10 of a cubic centimetre	1·5432	grains.
Centigram	1-100	10 cubic millimetres	0·1543	grain.
Milligram	1-1000	1 cubic millimetre	0·0154	grain.

Approved July 27, 1866.

Annex II.

Comparison of Yards and Metres.

1 metre = 1·093623 yards = 39·37043 inches.

Metres.	Yards.	Yards.	Metres.
1	1·093623	1	0·914392
2	2·1 7246	2	1·828784
3	3·280869	3	2·743175
4	4·374492	4	3·657567
5	5·468116	5	4·571959
6	6·561739	6	5·486351
7	7·655362	7	6·400743
8	8·748985	8	7·315134
9	9·842608	9	8·229526

Franklin Institute.

HALL OF THE INSTITUTE, Jan. 21st, 1880.

The stated meeting was called to order at 8 o'clock P.M., the President, Mr. William P. Tatham, in the chair.

There were present 198 members and 68 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and announced that ten persons were elected members of the Institute at their last meeting.

The Secretary reported the following donations to the Library:

Report of Proceedings of the Second International Meteorological Congress at Rome. 1879.
From the Meteorolog. Com. Royal Society.

Annual Report of the Comptroller of Currency. Dec. 1, 1879.
From J. J. Knox.

On the Coincidence of the Bright Lines of the Oxygen Spectrum with Bright Lines in the Solar Spectrum. By Henry Draper.

On Photographing the Spectra of the Stars and Planets. By Henry Draper. From the Author.

Third Annual Report of the Department of Public Works of Chicago for 1878. From D. S. Mead.

Annual Report of the Provost of the Peabody Institute of Baltimore for 1879. From the Institute.

Annual Report of the Secretary of War for 1879.
From the War Department.

Annual Report of New York Meteorolog. Observatory for 1878.
From D. Draper.

Journal of the Royal Geographical Society, Vol. 48.
From the Society.

Beiträge zur Anatomie u. Physiologie der Pulmonaten.
From Dr. Otto Nusslin.

Programm der Grossherzoglich Badischen Polytechnischen Schule zu Karlsruhe. From the School.

List of Vertebrated Animals now or lately Living in the Gardens of the Zoological Society of London. Seventh Edition. 1879.
From the Society.

Memoirs of the Geolog. Survey of India. Vol. 16, Part 1.

Memoirs of the Geolog. Survey of India. Palæontologia Indica. Ser. 2, Vol. 1, Part 4. Ser. 13, Part 1.
From the Geological Survey of India.

Received from Robert Grimshaw, Ph. D., 1445 Circulars, 824 unbound and 21 bound volumes of Catalogues, etc., of French and American Exhibitions.

Transactions of the American Institute of Mining Engineers. Vol. 7. From the Institute.

Report of the Commissioner of Fish and Fisheries for 1877.
From the Smithsonian Institution.

Report of the Fourteenth Industrial Exhibition of the Mechanics' Institute of San Francisco for 1879. From the Institute.

Exposition Universelle de Paris Catalogue Illustré de Machines pour Travailler le Bois. Par A. Ransome & Co. 1878.

Catalogue of Disston & Sons File Company, Philadelphia. 1876.
From R. Grimshaw, Ph.D.

Erster Jahresbericht der Geographischen Gesellschaft zu Hannover. 1879. From the Society.

Geolog. Survey of Japan. Reports of Progress for 1878 and 1879. By B. S. Lyman. From the Survey, Tokei.

Fourth Annual Report of the American Railway Master Mechanics' Association. 1871. From the Association.

American Ephemeris and Nautical Almanac for 1882. First Edition.

Narrative of the Second Arctic Expedition made by C. F. Hall. By J. E. Nourse. From the Navy Department.

The Queenslander. An Australian Weekly. 1877—1879.
From Hector Orr.

The President read the following

Annual Report of the Board of Managers.

The Board of Managers of the Franklin Institute respectfully submit to the Annual Meeting the following report of the transactions of the Institute during the year 1879:

Members.—During the year 125 persons were elected members of

the Institute, 33 have resigned, and there are now on our books the names of 1434 members in good standing. Of those members whose loss by death we have been called upon to notice particularly the Board will mention Mr. J. B. Knight, Secretary; Mr. Charles S. Close, Vice-President; Dr. Isaac Hayes, Mr. Henry C. Carey, Mr. Wm. Adamson and Mr. John Wise.

Treasurers' Report.—The following is a summary of the Treasurer's report for the year 1879:

Receipts.

Balance on hand Jan. 1, 1879,	$3,018.17	
Bloomfield Moore Trust Fund,	10,000.00	
Investments paid off,	8,000.00	
Receipts from all other sources,	11,755.45	
		$32,773.62

Payments.

Five per cent. Building Loan, and Interest,	$1,121.25	
Re-invested,	17,958.75	
All other payments,	12,287.77	
Balance on hand Dec. 31, 1879,	1,405.85	
		$32,773.62

This statement shows a reduction in the money and investments of the Institute by the operations of the year of $532.32. If, however, we take into account the improvement of the Library and building, the balance would be the other way.

Journal.—The JOURNAL of the Institute has continued under the direction of the Committee on Publication and the Secretary. This system, while it requires the unpaid-for labors of the members of the Committee, has otherwise worked well. During the past year, owing, as far as we know, to the excellence of the matter published, exchanges of the JOURNAL have been requested by both national and local scientific bodies in Europe, and the exchange list now embraces 161 scientific and technological periodicals, which are deposited in the Library for the use of members, and are duly bound for reference hereafter.

Drawing School.—The attendance upon the Drawing School has been larger than usual.

In the early part of last summer the Board arranged with the Pennsylvania Museum and School of Industrial Art to combine their efforts in this direction, and consequently the drawing school of that organi-

zation is now in satisfactory operation, under our roof, to mutual advantage.

To obtain the room necessary for this purpose, the models have been distributed over the building where they can be seen to most advantage, and the Cabinet of Minerals has been deposited with the Academy of Natural Sciences, subject to recall at any time.

In making this arrangement the Board was aware that the Franklin Institute contributed a larger proportion to the common effort than its proportion of the benefits resulting therefrom. But the Managers looked to the objects for which the Institute was erected, and desired to promote them in every way for the benefit of the citizens of Philadelphia.

The result proves the advantages of combination, and it may be profitably studied by other organizations whose special objects are embraced in our own.

Library.—The improvements of the Library have been continued during the year. The report of the Committee on the Library will present the details. During the last five years that committee has made a sustained effort, with the sums placed at its disposal, to bring up the Library to a condition adequate to satisfy the wants of the members; and although this state has not yet been reached, the Board esteem the progress already made as a matter of congratulation. The generous donation of $10,000, which established the Bloomfield Moore trust, will ensure the result desired.

Lectures.—During the early part of the year Prof. Elihu Thomson delivered five lectures on physical subjects, Prof. Frazer eight lectures on chemistry, Mr. J. B. Knight one lecture on ice, and Mr. D. S. Holman two lectures on life and motion as illustrated by the microscope.

In the arrangement of the courses this winter the same general plan has been adopted as heretofore, but in addition to the purely technical lectures, some upon topics of much general interest have been introduced.

In November Mr. Holman opened the course with a repetition of his lecture on motion and life, followed by four lectures by Prof. John M. Child on astronomical subjects. Mr. John Haug has also given a course of five lectures on mechanics, Dr. W. H. Greene three lectures on sugars and starches, bread-making and fermentation, Mr. C.

A. Ashburner, of the Pennsylvania Geological Survey, two lectures on petroleum, and Prof. Frazer is at the present time giving a very instructive course of eight lectures on modern chemistry, in which the new Hofmann apparatus, purchased for the Institute, is being used for the illustration, to great advantage.

In conclusion, the Board of Managers desire to press upon the members their duty of adding to the membership, until it shall bear something like the same proportion to the population of Philadelphia as existed when the Institute was first founded. No qualifications are required beyond a good moral character and nomination by members. If the new comer be a learner merely, he will have all the advantages of instruction the Institute can offer, which are greater than can be had elsewhere for the same cost. If he be a teacher, he may still find much to learn, with assistance for original research. Should he have no need or desire to benefit himself, he may find satisfaction in contributing a trifle for the benefit of others.

By order of the Board,

W. P. TATHAM, *President.*

Philadelphia, Jan. 21, 1880.

THE LIBRARY.

To the Franklin Institute:

The Committee on the Library respectfully report that there has been added to the Library during the past year:

Bound volumes,	. . .	1254
Unbound "	. . .	1836
Total,	. . . Vols.	3090

The number of bound volumes in the Library on the 31st day of December, 1879, was 14,813.

Valuable donations have been received from the different Bureaus of the United States Government, from Great Britain and from France. These donations, which have been properly acknowledged, have enabled the committee to complete the patent reports of the above mentioned governments, as also to add to the Library many maps and charts of great interest.

Ninety-eight *duplicate* volumes have been exchanged with other libraries, and with individuals, for books which were desirable for the Library of the Institute.

Thirty-three serial publications have been completed. Some of these are standard representatives of the progress of science and art in different departments represented by them, and in some cases the missing numbers were difficult to obtain.

Many models of historical interest from the old model-room have been distributed over the cases in the Library; these models, when properly labelled, will contribute to the interest of members of the Institute and to visitors.

There has been an increased interest in the Library shown by members, and the yearly increasing value of the collection of works representing all the departments of science and the arts offers an inducement to a larger number than is now enrolled on the list of members of the Institute to avail themselves of its privileges.

Respectfully submitted.

CHAS. BULLOCK, *Chairman of Com. on Library.*

January 13, 1880.

The Representative of the Institute in the Pennsylvania Museum and School of Industrial Art presented the following report:

The progress reported last year in this highly deserving institution we are happy to say has continued, and we trust the day is not far distant when its usefulness as a great art school will be acknowledged by all, and the wisdom of its foundation seen.

Under the able direction of a Curator, appointed early in the year, the arrangement of the various collections has been completed, and a system of registration of objects owned by or loaned to the Museum adopted, from which a catalogue can be made at any time.

In addition to the fine collection of medals and coins deposited by the American Philosophical Society, the Antiquarian Society of Philadelphia and the Library Company, Mr. Hockley has loaned to the Museum a very complete set of medals of the different Popes, etc., which are of great value from their historical connection and interest as works of art. It is to be hoped that the example set may be very generally followed, and many things deposited by their owners from time to time which will prove of great value to the student of art, and at the same time enhance the attractiveness of the display.

Early in the year the Grant collection of testimonials, deposited by Mr. George W. Childs, was loaned to the Pittsburg Library Exhibi-

tion, and still later it was sent to Chicago, with a representative collection from the Museum, for the Industrial Exhibition held in that city. By similar loans of works of art, under proper restrictions, it is hoped that not only will much good be done, but the general public be made aware of the importance of the collections, and extend to it more liberal aid.

The fine display of mineral and metallurgical specimens collected by the American Institute of Mining Engineers during the time of the Centennial, and which has been for some time stored in Memorial Hall, was in March last formally transferred to the Trustees, and early in June the collection was arranged and opened to the public. The value of this collection and its importance is so great as to merit its being classed as the most important event of the year.

A radical change has been made in the method of conducting the schools, and with the fall term they have been no longer free, but are carried on in the same rooms as our own, and upon the same terms. A gratifying increase in the number of the pupils attending is also to be noticed. The Ladies' Art Needlework Department has been transferred to an independent organization, and much interest being taken in the school, the change has proved a beneficial one.

Our late esteemed Secretary worked hard for the success of the institution that I have the honor to represent, and his death, in March last, has been severely felt by all connected with the Museum. Chairman of the Committee on Mechanic Arts, Mr. Knight, was untiring in all that would promote its welfare, while his training as an engineer admirably fitted him for this position, and the Museum was indeed fortunate in having his place so well filled by Mr. Frederick Graff.

ISAAC NORRIS, M.D.

January 21, 1880.

Mr. Cyrus Chambers, Jr., explained by photographic diagrams the construction of his new "Positive Register" for recording revolutions, and the machine was exhibited in operation, counting up to 5000 a minute with the greatest accuracy.

Hyzer and Lewellen's Portable Enamelling Furnace was shown, and some remarks were made upon its construction, the method of baking, etc., by Mr. Charles H. Roney. Specimens of the porcelain and tiles from the furnace were exhibited.

The Secretary's report included a paper giving some particulars of the manufacture and properties of Kerite, an invention of Mr. A. Goodyear Day. A fine exhibit of cables, of different sizes; tubing and insulated wire, were upon the table. The Saybolt Electrical Tester, for petroleum oils, was explained, and a photograph of the instrument thrown upon the screen. Attention was also called to Noyes' Dictionary Holder, and the "Beardmore Steam and Water Packing," composed of rubber and wire cloth, made at Akron, Ohio.

Mr. A. E. Outerbridge, Jr., of the United States Mint, described his visit to Menlo Park, and made some remarks on Edison's Electric Light. A lamp was exhibited, and photographs of the generator, etc., shown. The subject was discussed by Profs. Rogers and Thomson, Addison B. Burk and others.*

The tellers of the election held this day presented their report, and in accordance therewith the President declared the following members elected as officers and managers:

President, William P. Tatham.

Vice-Presidents, Henry Cartwright and Charles Bullock.

Secretary, Dr. Isaac Norris.

Treasurer, Frederick Fraley.

Managers to serve three years, C. H. Banes, C. Chabot, Prof. Persifor Frazer, W. Helme, Prof. E. J. Houston, E. Lewis, S. Sartain, J. J. Weaver.

Auditor, W. A. Cheyney.

Representative in the Pennsylvania Museum, Dr. Isaac Norris.

The tellers of the election not being able to agree whether certain proxies of members presented to them should be counted, Mr. J. J. Weaver moved that they be not received.

Dr. Rogers moved as an amendment that the whole subject be referred to a committee for a report, which was carried, and Messrs. Weaver, Rogers and McKean were named as the committee.

On motion, the following addition to the By-Laws, Article VIII, was unanimously agreed to: "In case of a vacancy in the office of Treasurer, it shall be the duty of the Board of Managers to appoint a person to fill the office *pro tempore*."

On motion, the meeting adjourned.

ISAAC NORRIS, M.D., *Secretary*.

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* A full report will appear in the next number of the JOURNAL.

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2. Each competitor must transmit to the Secretary of the Franklin Institute a memoir, describing in detail the apparatus, the mode of experimenting, and the results; and all memoirs received by him before the first day of January one thousand eight hundred and eighty, will, as soon as possible after this date, be transmitted to the Committee of Judges.

3. The Board of Managers of the Franklin Institute shall, before the first day of January, one thousand eight hundred and eighty-one select three citizens of the United States, of competent scientific ability, to whom the memoir shall be referred; and the said Judges shall examine the memoirs and report to the Franklin Institute whether, in their opinion, and, if so, which of their memoirs is worthy of the premium. And, on their report, the Franklin Institute shall decide whether the premium shall be awarded as recommended by the Judges.

4. Every memoir shall be anonymous, but shall contain some motto or sign by which it can be recognized and designated, and shall be accompanied by a sealed envelope, endorsed on the outside with same motto or sign, and containing the name and address of the author of the memoir. It shall be the duty of the Secretary of the Franklin Institute to keep these envelopes securely and unopened until the Judges shall have finished their examination; when, should the Judges be of opinion that any one of the memoirs is worthy of the premium, the corresponding envelope shall be opened, and the name of the author communicated to the Institute.

5. Should the Judges think proper, they may require the experiments described in any of the memoirs to be repeated in their presence.

6. The memoirs presented for the premium shall become the property of the Franklin Institute, and shall be published as it may direct.

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